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A SOCIAL NETWORK ANALYSIS OF THE NATIONAL MATERIALS COMPETENCY AT NAVAL AIR SYSTEMS COMMAND

by

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September 2002

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This thesis presents a social network analysis for the Naval Air Systems Command National Materials Competency. This geographically dispersed organization is responsible for conducting full-spectrum materials science and engineering across the full lifecycle of NAVAIR weapons systems. A Social Network Analysis (SNA) software tool was used to identify and diagnose the flow of knowledge and expertise across the enterprise. The SNA analysis is particularly important for the National Materials Competency because of a pressing need to provide advanced materials technologies and critical safety-related engineering solutions to the warfighter. For this research, the leaders of the National Materials Competency provided input regarding work interactions, communications and knowledge flows. The SNA software generated graphic visualizations that were used to analyze existing flow patterns. Analysis of the visualizations led to the identification of network topologies, structural holes, one- and two-way communication flows, and levels of cohesion within groups and sites. Based on the findings, recommendations for improved organizational performance include enhancements to network connectivity and cohesion, social capital, organizational processes and policies, information technology and knowledge management.

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A SOCIAL NETWORK ANALYSIS OF THE NATIONAL MATERIALS COMPETENCY AT NAVAL AIR SYSTEMS COMMAND

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ABSTRACT

This thesis presents a social network analysis for the Naval Air Systems Command National Materials Competency. This geographically dispersed organization is responsible for conducting full-spectrum materials science and engineering across the full lifecycle of NAVAIR weapons systems. A Social Network Analysis (SNA) software tool was used to identify and diagnose the flow of knowledge and expertise across the enterprise. The SNA analysis is particularly important for the National Materials Competency because of a pressing need to provide advanced materials technologies and critical safety-related engineering solutions to the warfighter. For this research, the leaders of the National Materials Competency provided input regarding work interactions, communications and knowledge flows. The SNA software generated graphic visualizations that were used to analyze existing flow patterns. Analysis of the visualizations led to the identification of network topologies, structural holes, one- and two-way communication flows, and levels of cohesion within groups and sites. Based on the findings, recommendations for improved organizational performance include enhancements to network connectivity and cohesion, social capital, organizational processes and policies, information technology and knowledge management.

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I. INTRODUCTION

> Network Centric Warfare is the vision for future Navy operations. Network centric warfare is based on the ability of a widely distributed, self-synchronizing force to mass effects when and where desired. The force, based on timely, accurate, common, shared information, requires high quality, widely distributed and netted sensors; a streamlined command structure; and units capable of autonomous operation and unity of effort.
>
> Vice Admiral Cebrowski, President, Naval War College

A. BACKGROUND

Network Centric Warfare is transforming operations throughout the U.S. Navy. One command, the Naval Air Systems Command (NAVAIR), has responded to this direction by creating a Competency Aligned Organization/Integrated Product Team (CAO/IPT) concept of operations. This transformation has allowed NAVAIR to organizationally align nearly 30,000 personnel located across eight geographic locations into national competencies. The leadership anticipates that this reorganization will improve the management of national assets and resources, enhance communications and collaboration, and establish full lifecycle organizational integration.

Integrating geographically dispersed, independent organizations into a single operational organization is a formidable challenge. Barriers to an effective organizational transformation can take many forms including legacy cultures and values, existing site performance metrics and reward systems, legacy workload distributions, and independent financial systems. NAVAIR continues to search for new tools and techniques to overcome these barriers and move the organization toward a more synergistic, efficient and productive organization.

One such tool is Social Network Analysis (SNA). SNA, with its increasing popularity, has shown to be an effective tool for identifying and diagnosing the flow of knowledge among organizational members. The resulting analysis allows senior management and technical leaders to design new organizational systems that improve the flow of critical knowledge and expertise throughout the organization.

B. PURPOSE

The purpose of this thesis is to provide an assessment of an existing NAVAIR Competency using Social Network Analysis (SNA) and to develop recommendations for improvement. Research includes an analysis of the social network of communications at the National Materials Competency organization, focusing on the flow of knowledge and expertise critical for its successful operation. The results of the SNA provide a foundation for assessing existing organizational processes for analysis, visualization, and interpretation.

C. RESEARCH QUESTIONS

The following questions address the identification and analysis of social networks within the NAVAIR National Materials Competency. These questions focus on organization communications, social network performance and the flow of knowledge and expertise:

1.) How do the national sites currently share knowledge and expertise in the national competency organization?

2.) To what extent does each site currently contribute, participate and collaborate in key National Materials Competency products and processes across the lifecycle?

3.) What patterns of relationships exist among National Materials Competency Leadership and Senior Technical Specialists?

4.) How can the efficacy of the NAVAIR Materials Division National Materials Competency be improved by enhancing the flows of knowledge and expertise?

D. BENEFITS OF STUDY

This study provides an assessment of the flow of knowledge within the NAVAIR Materials Division and National Materials Competency. The results of this study can be used to improve organizational performance and efficiency. Recommendations are made for establishing more effective networks and enhancing collaboration among organizational members.

E. SCOPE

This thesis studies the flow of knowledge and expertise that exists among the senior leadership of the National Materials Competency critical to National Materials Competency products and processes. Data are limited to 25 individuals because of the constraints of the student version of InFlow 3.0 SNA software.

F. ORGANIZATION OF STUDY

This study consists of six chapters. Chapter I provides a brief introduction and summary of this thesis. Chapter II consists of a background of the Naval Air Systems Command National Materials Competency organization, its history, strategic objectives, and concept of operations, and recently introduced branding initiative. Chapter III is a review of current literature including: Social Network Analysis, its history and purpose; the integral role of social capital, intellectual capital, and knowledge flow in high organizational performance; the application of SNA in organizations; and the use of SNA measures and metrics to characterize relations within organizational networks. Chapter IV describes the research methods including the survey and interview participation, data collection, and data analysis processes. Chapter V provides analysis and results including data compilation and Social Network Analysis measurements, metrics and visualizations. Chapter VI provides conclusions, implications, limitations and recommendations.

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II. BACKGROUND

A. OVERVIEW

During the mid-1990's, the Naval Air Systems Command sought to improve organizational efficiencies and operational effectiveness to meet its assigned mission. A major restructuring of the NAVAIR concept of operations was developed and deployed in conjunction with Base Realignment and Closure (BRAC) activities. NAVAIR transformed from a site independent, functional matrix concept of operations to a nationally integrated, Competency Aligned Organization/Integrated Product Team (CAO/IPT) construct. CAO/IPT was designed to promote stronger customer-supplier relationships, to more fully implement working capital fund financial systems, and align the organization along functional competencies where members are developed, empowered and deployed to support customer-sponsored activities as members of Integrated Product Teams (IPTs), Enterprise Teams (ETs), or Externally Directed Teams (EDTs).

B. ORGANIZATIONAL HISTORY

In 1995, the CAO/IPT concept-of-operations was formally established, creating clearly defined roles, responsibilities and linkages for technical disciplines within the Research and Engineering Group as described in the Naval Air Systems TEAM Engineering Competency Transition Plan. Organizational Breakdown Structure codes were established following a layered organizational hierarchy as shown in Figure 1.

Naval Air Systems Command

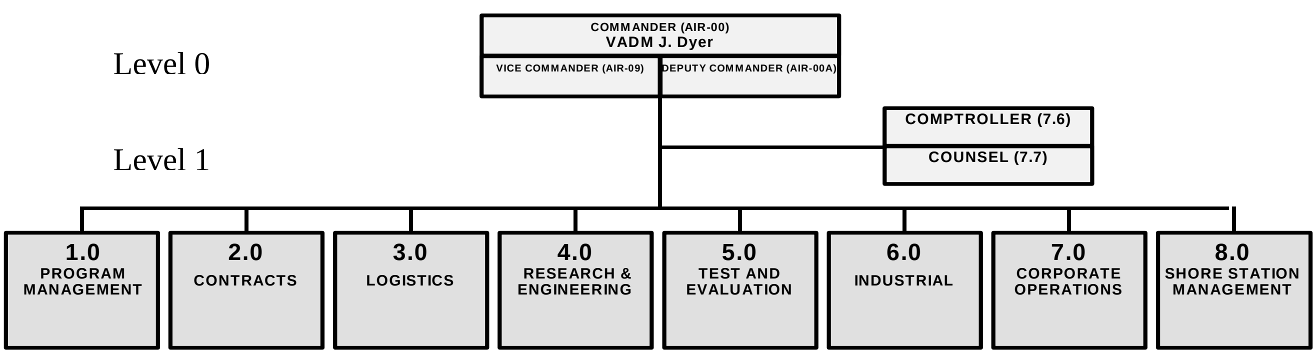

Figure 1. NAVAIR CAO Organizational Breakdown Structure

Level 0 and Level 1

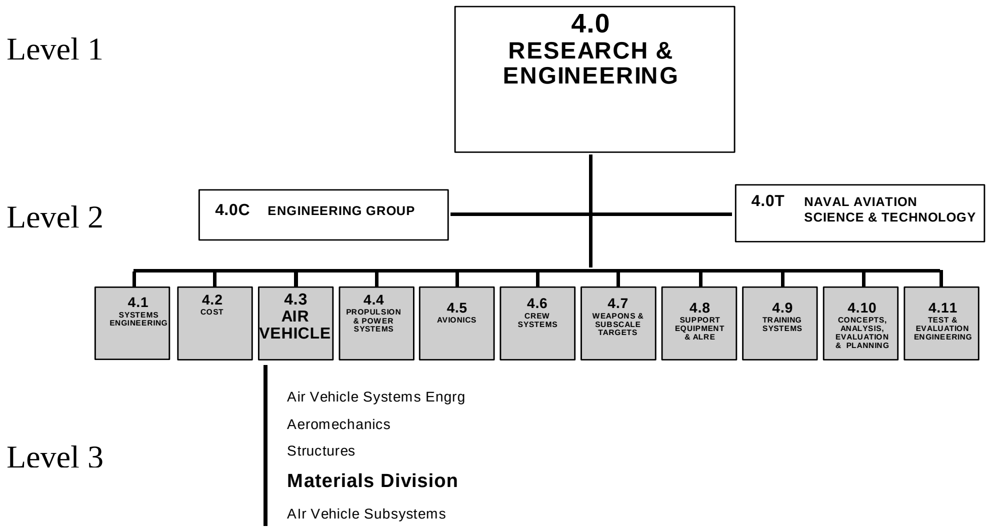

Figure 2. Organizational Structure Level 1, Level 2 and Level 3

Today, the National Materials Competency entitled, "the NAVAIR Materials Division," is a level 3 organization within the Air Vehicle Department of the Research and Engineering Group as shown in Figure 2. The Materials Division consists of the people, facilities, and equipment located at six sites: the Naval Air Warfare Centers Patuxent River, Maryland; China Lake, California; and Lakehurst, New Jersey; and the Naval Air Depots Cherry Point, North Carolina; North Island, California; and Jacksonville, Florida**.**

The NAVAIR Materials Division is responsible for conducting full-spectrum materials science and engineering across the full lifecycle of NAVAIR weapon systems. These full lifecycle activities include research and development of materials and processes, acquisition, and in-service engineering; and the selection, qualification, and safety-of-flight certification of advanced materials, manufacturing and maintenance processes for all naval aviation products. (Moore et al, 2002, p. 4)

The National Level 3 Materials Competency Leader is responsible and accountable for NAVAIR Materials Competency plans, programs, policies and processes. The Materials Management Board (MMB) was established by the National Materials Competency Leader to facilitate planning and execution of Materials Competency operations. The MMB is comprised of senior representatives from each site to provide administrative, operational, empowerment, and interface procedures to identify customer requirements, obtain resources, communicate, establish common processes, set technical policies, and define the roles, responsibilities, and expectations of all Materials Division personnel located at all sites.

C. STRATEGIC OBJECTIVES OF THE MATERIALS DIVISION

The Materials Division's strategic objectives follow the overall vision for the Naval Air Systems Command outlined in the Naval Aviation Systems Team's (TEAM) 2000-2005 Strategic Plan.

> One Team supporting the Warfighter, delivering 21st century aviation solutions, enabling dominance from the sea. One Team is a mindset that appreciates the value of individual contributions and diversity of ideas, while recognizing the power of the integrated enterprise. Warfighter requirements will be met with the best mix of solutions our Team has to offer – independent of our geographic boundaries. Common processes, financial systems, and knowledge management tools will increase our ability to respond quickly, delivering affordable, high value solutions every time. (NAVAIR, p. 2)

The Materials Division provides direction and guidance to other level 1, 2, and 3 competencies including Air Vehicle Structures, Air Vehicle Subsystems, Propulsion and Power, Avionics and Sensors, Crew Systems, Aircraft Launch and Recovery Equipment, Support Equipment, Weapons, Logistics and Industrial. The work of the competency results from a close interaction with other competencies, IPTs, EDTs, and ETs. The Materials Division aspires to fully leverage the expertise and capabilities of other Navy labs, Department of Defense, industry, universities, and other agencies to ensure superior products and services, and the incorporation of the best combination of materials and processes research, development and engineering principles, and practices. (Moore et al, 2002, p. 4)

D. COMPETENCY ALIGNED ORGANIZATION/INTEGRATED PRODUCT TEAMS

The Competency Aligned Organization/Integrated Product Team concept of operations is based on the key management principles originally sought by the Packard Commission of the mid-1980's, the Goldwater-Nichols Reorganization Act of 1986, the Defense Management Review of 1989, and many on-going Acquisition Reform Initiatives focused on improving the Department of Defense acquisition process. Clear delineation of individual responsibilities, the establishment of authority commensurate with such responsibilities (i.e., empowered individuals taking ownership of their areas of program or functional responsibility), and the efficient use of small high quality staffs, (i.e., trained, developed, empowered, and equipped with the necessary skills, tools, and work processes to be functionally proficient) are the overall characteristics of successful commercial and government projects that were the basis for a transition to CAO/IPT. (NAVAIR Acquisition Guide 2000, p. 3)

The major thrusts of the CAO/IPT concept of operations focus on how the Team effectively concentrates resources on the needs of our customers, and how the Team organizes to preserve and regenerate resources to meet the future needs of naval aviation. Under the guidance of the Commander's Team "Transition Plan" of 31 January 1994, and additional updates to the IPT Manual of December 1996 and the Team Transition Plan of February 1996, NAVAIR established fully empowered IPTs under the Program Manager – Aircraft leadership, to manage their assigned program responsibilities and resources from concept to disposal, (i.e., product focused lifecycle management) and a CAO to develop and sustain Team resources in support of IPTs and other needs. Program Managers have control over the supporting personnel at each site. The IPTs are responsible for spanning the complete program lifecycle, providing a responsive, single face to the customer, and improving our ability to control performance, cost and schedule. (NAVAIR Acquisition Guide 2000, p. 4)

The CAO aligns and links assets within specific disciplines to ensure the consistent application of people, processes and resources across all NAVAIR sites. These competencies provide organization-wide pools of talent and leadership to unify individuals who are doing similar work by common processes, and train and develop these people to proficiency in core competency skills. CAO allows the people, processes, and resources within the Naval Air Systems Command to be applied in a more tailored and efficient fashion within and across sites and teams. NAVAIR is now able to use its total capabilities from across all sites. The CAO functions to develop and nurture the necessary infrastructure to support the success of IPTs, EDTs and ETs to satisfy customer demand. (NAVAIR Acquisition Guide 2000, p. 4)

E. BRANDING INTIATIVE

In March 2002, the Naval Air Systems Command launched a Team-wide branding initiative to further align command efforts, to improve focus on the warfighter customer, and to support common goals, values and initiatives.

> First, we must ensure that our organizations, systems and processes are aligned to deliver exactly what they're designed to produce – a combat-capable Navy, ready to sail into harm's way. Second, alignment involves clear communication, from the recruiter to the CO to the CNO. It's about communicating realistic expectations and then helping sailors accomplish realistic goals – in a word, credibility.
>
> ADM V. Clark, CNO

To institute NAVAIR's brand, three key documents were developed:

- The Warfighter Bill of Rights
- NAVAIR: The Charter
- NAVAIR: The Credo – Principles of Alignment

The NAVAIR Warfighter Bill of Rights makes NAVAIR's commitment clear and provides a useful tool for the warfighter. The NAVAIR Charter provides a clear declaration of purpose for the Command. And, NAVAIR's Credo provides a distillation of the NAVAIR story and provides the principles that will guide future Command actions and plans. Appendix A provides the Credo – Principles for Alignment (https://projectgoldenwing.navair.navair.navy.mil)

F. NATIONAL MATERIALS COMPETENCY STRUCTURE

The National Materials Competency was established at each NAVAIR site that employed resident materials research and engineering personnel. Members of the National Materials Competency were mapped to specific level 4 technical disciplines as defined in the Organizational Breakdown Structure (OBS). National Materials Competency leadership positions were established at levels 3 and 4 for national technical leadership across each OBS level 4 organization. In addition, local site level 3 and level 4 supervisory and technical management positions were established to provide on-site policies and processes. Organizational networks began to form within and across the Materials Competency level 3 and level 4 organization under the auspices of the Materials Management Board. The performance of these newly formed, nationally dispersed organizational networks remains critical to successfully meeting customer mission requirements.

The six level 4 competencies as shown in Figure 3 comprise the National Materials Competency and NAVAIR Materials Division by OBS code include:

- Code 4.3.4.1 Metals/Ceramics
- Code 4.3.4.2 Industrial/Operational Chemicals
- Code 4.3.4.3 Nondestructive Inspection
- Code 4.3.4.4 Polymers/Composites
- Code 4.3.4.5 Analytical Chemistry and Testing
- Code 4.3.4.6 Corrosion/Wear.

A detailed description of Competency functions is provided in Appendix B.

The Materials Division is dispersed geographically as shown in Figure 4. Each site has its assigned principle mission and principle programs to support. Each site also consists of laboratory capabilities to perform research and engineering evaluations and testing.

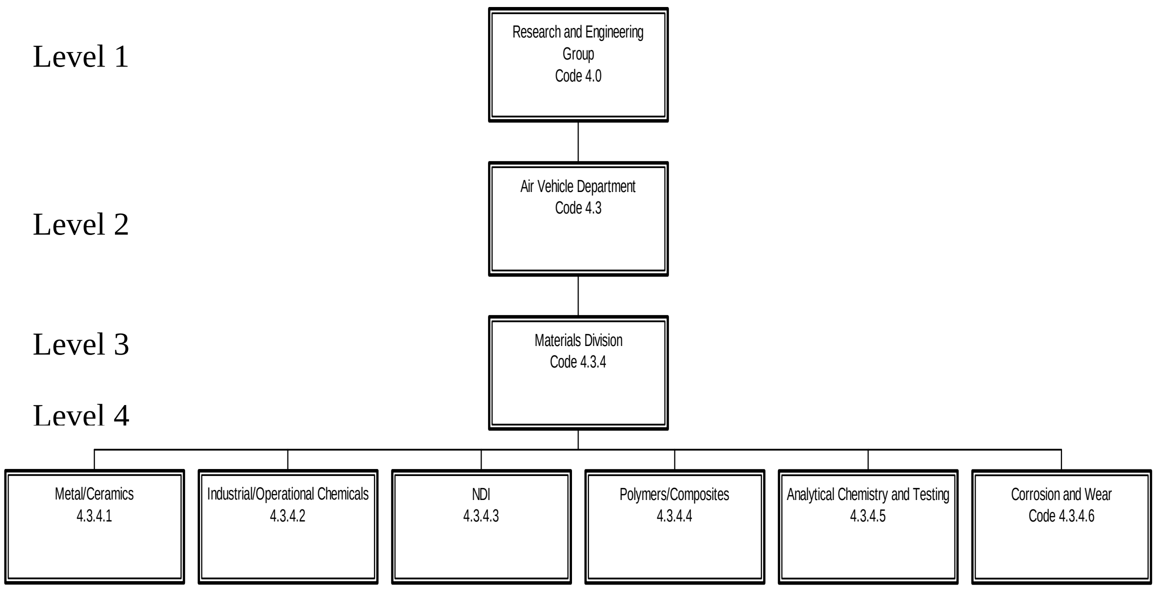

Figure 3. Materials Division Organizational Breakdown Structure

National Naval Aviation Materials Competency

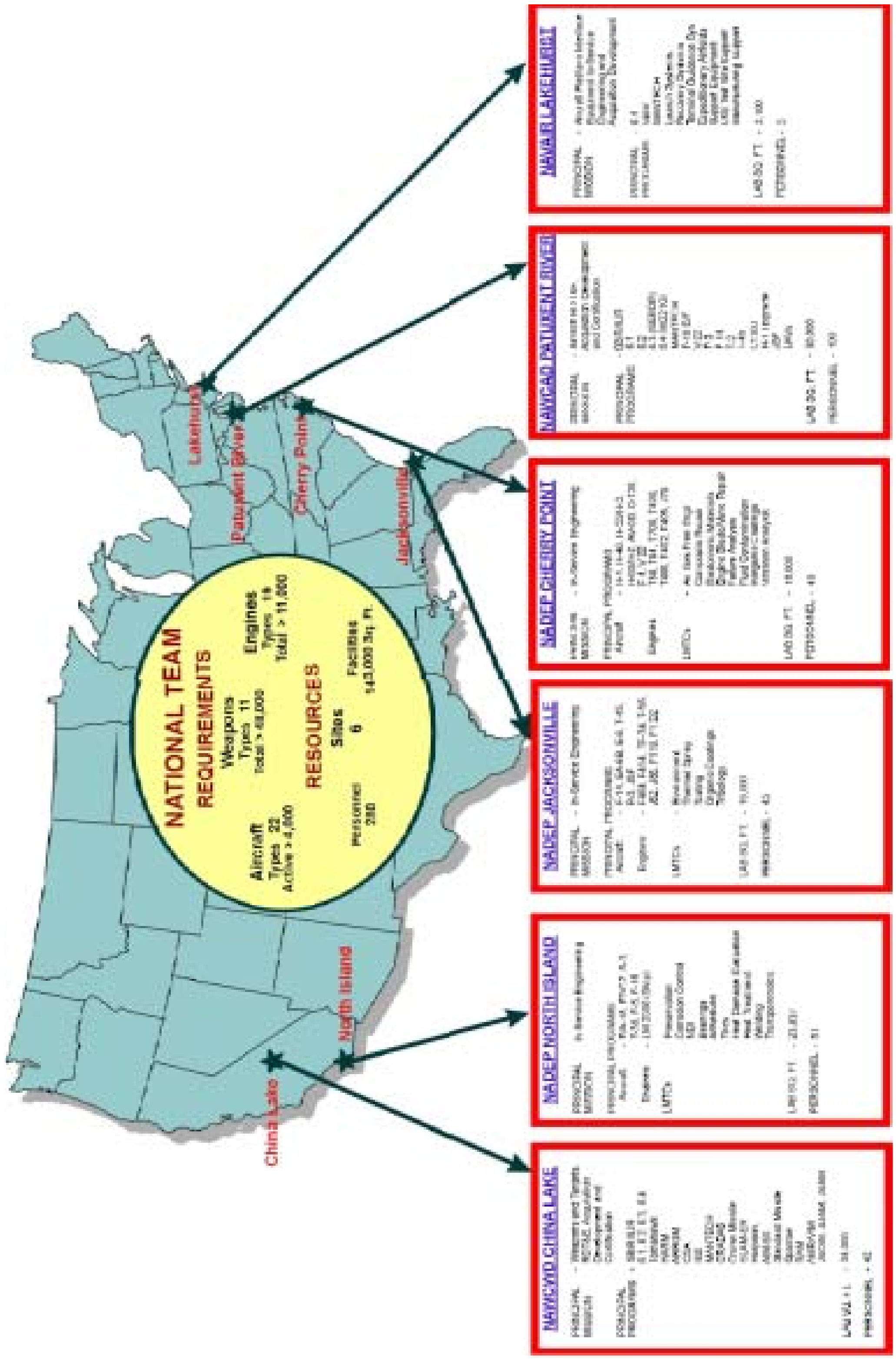

Figure 4. National Materials Competency Organizational Map

Coordination across all sites, both the level 3 Materials competency-wide level as well as across the national level 4 organizations, represents a strong challenge to produce the efficiencies enabled by the Competency Aligned Organization construct.

To conduct an effective SNA of the NAVAIR National Materials Competency, a comprehensive understanding of current research on SNA applications, concepts, tools and methodologies is necessary.

III. LITERATURE REVIEW

A. OVERVIEW

In today's fast paced knowledge-intensive economy, work of significance is increasingly accomplished collaboratively through informal networks. (Cross, 2002, p. 41) As intellectual capital and knowledge creation play increasingly important roles in tomorrow's economy, the ability to employ integrated knowledge in the core competencies of an enterprise may provide an unprecedented basis for competitive advantage. (Nissen, 1998, p. 21) Transforming enterprises into "world class" operations requires an approach that uses the knowledge and experience diffused throughout the organization.

The study of Social Network Analysis is growing as researchers demonstrate the extent to which informal networks pervade and affect life and work within organizations. (Scott, 2000, pp. 33-34) A Social Network is defined by Weyers as,

> "an autonomous form of coordination of interactions whose essence is the trusting cooperation of autonomous, but interdependent agents who cooperate for a limited time, considering their partners interests, because they can thus fulfill their individual goals better than through non-coordinated activities." (Gans, 2001, p. 154)

SNA provides a formal, conceptual means for thinking about the social world and is based on the assumption that the relationships among interacting units are of importance. It provides a research tool that evaluates the relationships between people and organizations and is widely used in the social and behavioral sciences, as well as economics, marketing and industrial engineering. SNA is able to view the social environment and focus on the patterns or structures of relationships among interacting entities such as communications among members of a group, trade among nations, or transaction between corporations. These relations and patterns of relations require methods and analytic concepts that are distinct from traditional statistics and data analysis. Central principles have been developed that distinguish SNA from other research approaches. The following concepts are important with regard to SNA:

a. Actors and their actions are viewed as interdependent rather than independent, autonomous units

b. Relational ties or linkages between actors are channels for transfer or "flow" of resources (either material or nonmaterial)

c. Network models focusing on individuals view the network structural environment as providing opportunities for or constraints on individual action.

d. Network models conceptualize structure (social, economic, political, and so forth) as lasting patterns of relations among actors. (Wasserman, 1994, pp. 4-11)

SNA characterizes the observed attributes of actors in terms of patterns or structures of ties among units. These relational ties are the primary focus while the attributes of individual actors are considered secondary. The relational ties among actors may be any relationship that exists between units such as transactions, communications, interactions, flow of resources and others. Measurements and visualization of these networks are central to conducting SNA.

Important relationships exist between social capital, knowledge flow, and intellectual capital. The effective flow of knowledge and expertise is dependent on social capital and is necessary to produce and develop intellectual capital within organizations. SNA provides a relevant tool to characterize the existing flow of knowledge and expertise. This chapter reviews the literature on Social Network Analysis including its history and purpose, as well as its relationship to social capital, intellectual capital, and knowledge flow.

B. HISTORY OF SOCIAL NETWORK ANALYSIS

A sociogram is defined as a picture in which people (or more generally, any social units) are represented as points in two dimensional space, and relationships among pairs of people are represented by lines linking the corresponding points. This innovation developed by Moreno along with Jennings in the early 1930's marked the beginning of sociometry, the precursor to social network analysis. Sociometry is the measurement of interpersonal relations in small groups. (Wasserman, 1994, pp. 8-11)

Contemporary Social Network Analysis (SNA) was forged during the early 1960's and 1970's at Harvard where three main traditions were brought together: the sociometric analysts, who worked in small groups and produced a number of technical advances in graph theory; the Harvard researchers who explored patterns of interpersonal relations and the formation of cliques, and the Manchester anthropologists who investigated the structure of community relations in tribal and village societies. (Scott, 2000, p. 7)

At Harvard, two key mathematical breakthroughs occurred. The first was the development of algebraic models of groups using set theory to model kinship and groups. The second was the development of multidimensional scaling for translating relationships into social distances for mapping them in a social space. The Harvard group developed as mathematically-oriented structural analysts, focusing on the modeling of a broad range of social structures. Much of the effort of the Harvard group was focused in the International Network for Social Network Analysis (INSNA), which was founded in Toronto, Canada. Sociologists and communications scientists now use SNA to describe relationships, examine flows, and analyze patterns that develop between individuals and organizations. (Scott, 2000, p. 34)

C. PURPOSE OF SOCIAL NETWORK ANALYSIS

SNA provides methods and tools to map the patterns of information flow (or more frequently the lack of it) across functional boundaries and barriers, and can yield critical insight into where management should target efforts to promote collaboration that provide strategic benefit. SNA can identify and assess the health of strategically important networks such as the core functions of an organization, research and development departments, and strategic business units by making visible otherwise invisible patterns of interaction. SNA makes it possible to facilitate and manage these networks for more effective collaborations and knowledge sharing. (Cross, 2002, p. 29-41) Social Network Analysts seek to describe networks of relations as fully as possible, identify prominent patterns in the networks, trace the flow of information (and other resources) through them, and discover what effects these relations have on people and organizations. (Garton, 1997, p. 3)

SNA can be used to determine the connectivity of groups including the amount of cohesion as well as fragmentation. It can used to evaluate the formation and impact of sub-groups, the constraints and distributions of flows, the synergy within an organization, and the prominence or centrality of individuals or groups. SNA can be a very useful means of assessing the impact of strategic restructuring initiatives on the informal structure of an organization. It provides a snapshot for executives that can be used to gain agreement on what problems need to be addressed in a distributed group, what appropriate interventions need to be taken, and also provides the ability to conduct follow-up analysis to ensure that interventions provide the desired impact. (Cross, 2002, pp. 36-37)

Increasingly, as organizations restructure, work is performed through these informal networks of relationships. Movement toward de-layered, flexible organizations and emphasis on supporting collaboration in knowledge-intensive work has made it increasingly important for executives and managers to address the informal networks within their organizations. The informal relationships among employees are often far more reflective of the way work happens within an organization than relationships established by position within the formal structure. Situations can exist where actor's expertise is not being tapped while other actors can appear like bottlenecks, or constraints to the flow of information or knowledge. Organizational or technological improvements can be designed to address social network challenges identified through SNA. For example, new communication forums can be established such as weekly meetings, video-teleconferences, tele-cons, or new sub-groups can be established around communities of practice to address specific areas needed for improvement. (Cross, 2002, pp. 36-37)

The recent shift toward innovation often demands critical collaboration within and between functional units, divisions, and even entire organizations requiring tools and capabilities to understand where collaboration is, and is not occurring. (Cross, 2002, p.

25-32) Similarly, an understanding of why collaboration is or is not occurring within social networks is important to provide a basis for performance enhancement.

D. SOCIAL CAPITAL

Social Capital is defined as the wealth or benefit that exists because of an individual's social relationships. It is the positive interactions that occur between individuals in a network that lead to the formation of social capital. Social capital, like other forms of capital, is productive, making possible the achievement of certain ends that in its absence would not be possible. Francis Fukuyama, who has written extensively on the subject of trust suggests that, "Social Capital is the capability that arises from the prevalence of trust in a society or in certain parts of it." (Lesser, 2000, pp. 4-20) Social relations between actors constitute a form of social capital that provides information that facilitates actionable knowledge. (Coleman, 2000, p. 25) There are three primary dimensions that influence the development of these benefits: the structure of relationships, the interpersonal dynamics that exist within these structures, and the common context and language held by individuals within the structure. (Lesser, 2000, p. 4)

Bourdieu defines social capital as decomposable into two elements: first, the social relationship itself allows individuals to claim access to resources possessed by their associates, and second, the amount and quality of those resources. (Portes, 2000, p. 45) Social capital resides in relationships, and relationships are created through exchange. The pattern of linkages and the relationships built between them are the foundation of social capital. The process in which social capital is created and sustained through exchange and in which, in turn, social capital facilitates exchange which is the precursor to resource combination. (Nahapiet, 2000, p. 132)

The fundamental proposition of social capital theory is that the network ties provide access to resources and that social relations constitute information channels that reduce the amount of time and investment required to gather information. Linkages or ties provide the channels for information transmission and are an important facet of social capital that may impact the development of intellectual capital. Three properties of network structure: density, connectivity, and hierarchy, are all features associated with flexibility and ease of information exchange through their impact on the level of contact or the accessibility they provide to network members. The diversity within the network is very important because it is well established that significant progress in the creation of intellectual capital often occurs by bringing together knowledge from disparate sources and disciplines. Networks, and network structures represents facets of social capital that influence the range of information that may be accessed and that becomes available for combination. As such, these network structures become a valuable resource as channels or conduits for knowledge diffusion and transfer. (Nahapiet, 2000, pp. 134-135)

One of the primary drivers behind the interest in social capital is the rise of the knowledge-based organization. As knowledge begins to supplant land, labor, and capital as the primary source of competitive advantage, the ability to create new knowledge, share existing knowledge, and apply organizational knowledge to new situations becomes critical. (Lesser, 2000, p. 9) Increasingly companies and organizations will differentiate themselves on the basis of what they know. The special capabilities of organizations for creating and transferring knowledge are being identified as a central element of organizational advantage. Social capital theory provides a sounds basis for explaining why this should be the case. First, organizations as institutional settings are characterized by many factors known to be conducive to the development of high levels of social capital. And second, it is the coevolution of social and intellectual capital that underpins organizational advantage. (Nahapiet, 2000, p. 141) Social capital facilitates the development of intellectual capital by affecting the conditions necessary for exchange and combination to occur. (Nahapiet, 2000, p. 132)

Social Capital is directly linked to an organization's ability to effectively flow data, information and ultimately knowledge and expertise to produce quality products and services competitively. Scholars widely recognize that innovation generally occurs through combining different knowledge and experience and that diversity of opinion is a way of expanding knowledge. Meaningful communication is an essential part of social exchange and combination processes. There is much evidence to support the view that the combination and exchange of knowledge are complex social processes and that much valuable knowledge is socially embedded in particular situations, in coactivity, and in relationships. Knowledge creation involves making new combinations, incrementally or radically, either by combining elements previously unconnected or by developing novel ways of combining elements previously associated. Social capital facilitates the development of intellectual capital by affecting the conditions necessary for exchange and combination to occur. (Nahapiet, 2000, pp. 119-149)

E. INTELLECTUAL CAPITAL

Intellectual capital is defined as the knowledge and knowing capability of the social collective. Fundamentally, intellectual capital is a social artifact and knowledge and meaning are always embedded in a social context – both created and sustained through ongoing relationships in collectives. (Nahapiet, 2000, pp. 119-149)

New intellectual capital is created through combination and exchange of existing intellectual resources, which may exist in the form of explicit and tacit knowledge. (Nahapiet, 2000, pp. 119-149) Explicit knowledge is typically formalized through artifacts such as books, letters manuals, standard operating procedures and instructions. Tacit knowledge pertains to understanding and expertise contained within the minds of people and is related to highly complex tasks that are harder to capture in formal organizational procedures. Tacit knowledge is developed while working on projects through socialization and sharing of experience and expertise over time in micro-communities of knowledge. (Krogh, 2000, p. 82)

The special capabilities of organizations for creating and transferring knowledge are increasingly being identified a central to organizational advantage. It is the co-evolution of social and intellectual capital that underpins organizational advantage. (Nahapiet, 2000, pp. 119-149)

F. KNOWLEDGE FLOW

The primary objective of knowledge flow is to enable the transfer of capability and expertise from where it resides to where it is needed – across space, time and organizations as necessary. The problem is that knowledge is not evenly distributed throughout an enterprise, and large geographically-dispersed, time-critical enterprises are prone to knowledge "clumping." Knowledge "clumps" are analogous to blood clots that can impede and obstruct the life-sustaining flow of a human circulation system, which can lead to pain, paralysis, and even death. Similarly, an uneven distribution of knowledge can be crippling to an organization or enterprise without effective systems and processes to enable knowledge to flow freely. Knowledge is proving difficult to manage, and knowledge work has been stubbornly resistant to reengineering and process innovation. (Nissen, 2001, pp. 1-2)

Knowledge networks constitute part of the current concept of a knowledge-based organization in which managing knowledge flows is one of the most important tasks. The challenge for technology management is: How to organize and manage the knowledge generating and sharing networks so that the probability of successful innovation will be increased and the time for final results is reduced under the constraints of the resources available. (Pelc, p. 718) Knowledge enables action and has long been ascribed to successful individuals in organizations, but today it is pursued at the enterprise level through a practice known as knowledge management. Knowledge capital is commonly discussed as a factor of no less importance than the traditional economic inputs of labor and finance, and the concept of knowledge equity is now receiving theoretical treatment through research. Drucker writes, "Knowledge has become the key economic resource and the dominant – and perhaps even the only – source of competitive advantage." (Drucker, 1995 p. 271) It follows that increasing knowledge-work productivity represents the great management challenge of the century. Brown and Duguid add, "organizational knowledge provides synergistic advantage not replicable in the marketplace." (Brown, 1998, p. 90) Forecasts estimate that knowledge work will account for nearly 25% of the workforce soon after the 21st century begins. (Nissen, 2001, p. 1) Conventional organization structures rely heavily on informal networks and communities of practice for storing and disseminating knowledge. And, increasingly organizational activities are being executed in the context of modified organizational forms enabled by information technology, such as virtual or networked organizations. (Nissen, 2000, p. 34)

Many scholars share the notional view that knowledge supports action directly and is distinct from data and information. Data is required to produce information, and information involves more than just data. (Nissen, 2002, p. 253) Similarly, information is required to produce knowledge, but knowledge involves more than just information. Knowledge enables action. (Nissen, 2001, p. 3)

Knowledge and knowledge flow can be described in a number of ways within an organization. Nonaka describes knowledge-creation as primarily an individual activity, performed by knowledge workers that are mostly professional, well-educated and relatively autonomous, often with substantial responsibility within an organization. (Nissen, 2000, pp. 1-2) Nonaka describes four dimensions as the principal drivers of knowledge flow:

a) Socialization Flow: Where members of a team or group share experiences and perspectives flowing from the individual to the group level.
b) Externalization: Denotes the use of metaphors through dialog that leads to articulation of tacit knowledge and its subsequent formalization to make it concrete and explicit.
c) Combination: Denotes the coordination between team members and other groups in the organization, along with documentation of existing knowledge – to combine new concepts from within teams through externalization with other explicit knowledge in the organization.
d) Internalization: Denotes diverse members of the organization applying combined knowledge from above – often through trial and error – and in turn translating such knowledge into tacit form at the organizational level.

Knowledge can be described as existing in various states at an individual level. Bloom offers six states of knowledge, (Nissen, 2001, p. 11) operationalized according to the kind of action taken:

a) Memorization - to commit knowledge to memory

b) Comprehension - to understand knowledge fully
c) Application - to put knowledge to use
d) Analysis - an examination of knowledge to understand
e) Synthesis - to reason deductively
f) Evaluation - to determine the value of the use of knowledge

Similarly, Nissen identifies six stages (Nissen, 2001, p. 11) from which knowledge flows as part of a knowledge management lifecycle at the organizational level:

a) Creation - the act of inventing or producing knowledge
b) Organization - to structure into a coherent form
c) Formalization - to provide knowledge a formal status
d) Distribution - to distribute across the organization
e) Application - to put knowledge to use
f) Evolution - growth to a higher level of knowledge

Knowledge enabling is defined as the overall set of organizational activities that positively affect knowledge creation. Knowledge enabling includes facilitating relationships and conversations as well as sharing local knowledge across an organization or beyond geographic and cultural borders. (Von Krogh, 2000, pp. 4-7) The fabric of social capital and the social networks that support it facilitate knowledge creation at the organizational level. Von Krogh identifies the five knowledge creation steps:

a) Sharing tacit knowledge - exchanging experience and expertise
b) Creating concepts - inventing new ideas or knowledge
c) Justifying concepts - validating the ideas or knowledge
d) Building a prototype - developing a product from the knowledge
e) Cross-leveling knowledge - sharing knowledge across groups

G. CONTEMPORARY ORGANIZATIONAL CONSIDERATIONS

Over the past decade, significant restructuring of organizations has resulted in fewer hierarchal layers and more permeable internal and external boundaries. The byproduct of these restructuring efforts is that coordination and work are increasingly performed through informal networks of relationships rather than rigid organizational hierarchies and communication channels. These informal networks are not found on organizational charts. However, these informal networks often promote organizational flexibility, innovation, and efficiency as well as quality of products and services by virtue of effectively pooling unique expertise. Therefore, supporting collaboration and work within these informal networks is becoming increasingly important, especially for those companies competing on knowledge and the ability to innovate and adapt. (Cross, 2002, p. 25)

Critical informal networks are often hampered by competition, organization formal structures, work processes, geographic dispersion, human resource practices, politics, not-invented-here mentality, leadership styles and cultures which run counter to an organization's overall performance objectives. This is a particular problem in knowledge-intensive settings where management is counting on collaboration among employees with different types of expertise. In addition, both practical experience and scholarly research indicate significant difficulty getting people with different expertise, backgrounds, and problem solving styles to effectively integrate their unique perspectives. As organizations move toward de-layered, flexible organizations and emphasis is being placed on knowledge-intensive work, it is becoming increasingly important to address the informal networks within organizations. Research clearly indicates ways managers can influence informal networks at both the individual and whole network levels, however, relatively little is done to assess and support critical, but often invisible, informal networks in organizations. SNA can be an invaluable tool for systematically assessing and then intervening at critical points within an informal network. (Cross, 2002, pp. 25-26)

Organizations must concurrently conduct a broad range of differentiated but interdependent tasks, e.g. research and development, product development, manufacturing, marketing, customer support, planning and corporate development. The execution of each of these tasks involves multiple interactions and interfaces between organizational units and individuals that occur with varying frequency and have different levels of impact on performance and decision processes. This problem is further complicated by the fact that interactions are often strongly influenced by factors such as proximity and the modus of interaction, e.g. concurrent (face-to-face, meetings, telephone, videoconferences) vs. non-concurrent (documents, e-mails, fax). (Mann, 1998, p. 185) In the modern office environment, computer-supported cooperative work (CSCW) refers to work carried out by a group of individuals with computer and network support, especially applicable where people work together in dynamically formed groups to accomplish a particular task. CSCW operates in four modes: synchronous, distributed synchronous, asynchronous, and distributed asynchronous. CSCW provides the most common means for participant interaction offering potential advantages in scalability, reliability, extensibility, maintainability and flexibility of resulting systems. (Temdee, p. 1) Also, recent studies have suggested that the use of e-mails flattens traditional top-down organization structures by providing people with new communications opportunities that circumvent traditional reporting channels. (Mead, 2001, p. 6)

It has been found that informal networks are increasingly important contributors to employee job satisfaction and performance. (Cross, 2002, p. 41) To many senior executives, these intricate webs of communication are unobservable and ungovernable. (Cross, 2002, p. 105) SNA provides a means with which to identify and assess the health of strategically important networks within an organization by making invisible patterns of interaction visible, enabling management to work with organizations and groups to facilitate effective collaboration. With SNA, managers have a means to assess the effects of decisions on the social fabric of an organization. (Cross, 2002, p. 41)

H. SOCIAL NETWORK ANALYSIS MEASURES AND METRICS

SNA provides tools that help analyze and visualize organizational networks in specific focus areas. A variety of analytical tools are now available, which when combined with collected data and processed into metrics and graphical representations, can accurately describe a revealing portrayal of organizational or group dynamic relationships, flows, communications, and transactions and provides a useful approach to analyze the effect of information technologies. (Mead, 2001, pp. 2-8)

In the context of organizational communications, network analysts often identify the entities as people who belong to one or more organizations and to which are applied to one or more communications relations, such as “provides information to,” “gets information from,” and “communicates with.” It is also common to use work groups, divisions and entire organizations as the set of entities and explore the variety of relations. (Monge, p. 441)

The following tables provide a number of typical measures important in SNA at three distinct, but related levels of observation. Table 1 provides typical social network measures assigned to individual actors. These measures describe the characteristics of the individuals or nodes on a social network and their relationship attributes relative to the other nodes in the networks. (Monge, pp. 442-444)

Measure	**Definition**
Degree	Number of direct links with other actors
In-degree	Number of directional links to the actor from other actors (in-coming links)
Out-degree	Number of directional links from the actor to other actors (out-coming links)
Range (diversity)	Number of links to different actors (others are defined as different to the extent that they are not themselves linked to each other, or represent different groups or statuses)
Closeness	Extent to which an actor is close to, or can easily reach all the other actors in the network. Usually measured by averaging the path distances (direct and indirect links) to all others. A direct link is counted as 1, indirect links receive proportionally less weight
Betweenness	Extent to which an actor mediates, or falls between any other two actors on the shortest path between those actors. Usually averaged across all possible pairs in the network
Centrality	Extent to which an actor is central to a network. Various measures (including degree, closeness, and betweenness) have been used as indicators of centrality. Some measures of centrality weight an actors links to others by centrality of those actors.
Prestige	Based on asymmetric relationships, prestigious actors are the object rather than the source of relations. Measures similar to centrality are calculated by accounting for the direction of the relationship (ie. in-degree).
Star	An actor who is highly central to the network
Liaison	An actor who has links to two or more groups that would otherwise not be linked, but is not a member of either group
Bridge	An actor who is a member of two or more groups
Gatekeeper	An actor who mediates or controls the flow (is the single link) between one part of the network and another
Isolate	An actor who has links, or relatively few links to others

Table 1. Typical Social Network Measures Assigned to Individual Actors
(Adapted from Brass, 1995)

Table 2 provides typical social network measures used to describe ties or linkages between actors' networks. These measures focus on assessing the linkage characteristics between the actors or nodes. They provide important insight into the characteristics of an individual and the relationships between one or more nodes. (Monge, pp. 442-444)

Measure	**Definition**	**Example**
Indirect Links	Path between two actors is mediated by one or the other	A is linked to B, B is linked to C; thus A is indirectly linked to C through B
Frequency	How many times, or how often do the links occur	A talks to B 10 times per week
Stability	Existence of link over time	A has been friends with B for 5 years
Multiplexy	Extent to which two actors are linked together by more than one relationship	A and B are friends, they seek out each other for advice, and work together
Strength	Amount of time, emotional intensity, intimacy, or reciprocal services (frequency or multiplexity often used as a measure of strength of tie	A and B are close friends, or spend much time together
Direction	Extent to which link is from one actor to another	Work flows from A to B, but not from B to A
Symmetry	Extent to which relationship is bi-directional	A asks B for advice, and B asks A for advice

Table 2. Typical Social Network Measures of Ties (Adapted from Brass, 1995)

This thesis addresses the metrics used to measure the network as a system. Table 3 provides typical social network measures used to describe networks at an organizational level. Network metrics characterize the overall nature and extent of the network and its characteristics for use in network analysis. Network measures can provide a relative measure of the network’s characteristics to the theoretical possible measures such as inclusiveness, density, centralization, and connectedness. (Monge, pp. 442-444)

Measure	**Definition**
Size	Number of actors in the network
Inclusiveness	Total number of actors in the network minus the number of isolated actors (not connected to other actors). Also measured as the ratio of connected actors to the total number of actors
Component	Largest connected subset of network nodes and links. All nodes in the component are connected (either direct or indirect links) and no nodes have links to nodes outside the component
Connectivity (reachability)	Extent to which actors in the network are linked to one another by direct or indirect ties. Sometimes measured by the maximum, or average, path distance between any two actors in the network
Density	Ratio of the number of actual links to the number of possible links in the network
Centralization	Difference between the centrality scores of the most central actor and those of other actors in a network is calculated, and used to form the ratio of the actual sum of the differences to the maximum sum of the differences
Symmetry	Ratio of the number of symmetric to asymmetric links (or to total number of links) in a network
Transitivity	Three actors (A, B, C) are transitive if whenever A is linked to B and B is linked to C, then C is linked to A. Transitivity is the number of transitive triples divided by the number of potential transitive triples (numbers of paths of length 2)
Connectedness	Ratio of pairs of nodes that are mutually reachable to total number of pairs of nodes

Table 3. Typical Social Network Measures Used to Describe Networks

(Adapted from Brass, 1995)

One of the key methods used to understand networks and their participants is to evaluate the location of actors in the network. Measuring the network location is finding the centrality of the node, which helps to determine the importance, or prominence of a node in a network. All sociologists would agree that power is a fundamental property of social structures. Power is inherently relational. An individual has power at a micro level (between individual actors), or as a macro property across an entire organization. Having power in a favored position means that an actor has more opportunities, influence and insights into the network's activities. However, network analysts are more likely to describe their approaches as descriptions of centrality rather than power. Three popular centrality measures are degrees, betweenness and closeness which describe an individual's location in the network in terms of how close they are to the "center" of action. Degrees are the number of direct connections or links a node has in the network.

Actors which have more ties to other actors may have an advantage since they have many ways to satisfy needs and are less dependent on others. An actor who receives many ties are referred to as prominent or to have high prestige. Actors who have high out-degree centrality are more influential because they are able to better express their views.

For this thesis the following SNA metrics are used. The overall network global connectivity (k) is defined the sum of all of the network connections. (Krebs, 2002) The overall global density (D) of the network is defined as:

(1) $D = kN/(N(N-1)/2) = 2k/N-1$

where: N is the population size (IMAGES) (Amblard, 2001, p. 6)

Common wisdom might consider that the more connections the better but what really matters are where the connections lead and how they connect the otherwise unconnected. Interactions between two nonadjacent actors might depend on the other actors in the network that might have some control over interactions. Betweenness is a measure which reflects an actors centrality between other actors in the network. One could envision that actors "in the middle" exert more "interpersonal influence" on the others. (Wasserman, 1994, pp. 188-190) Betweenness centrality views actors as being in favored positions to the extent that the actor falls on the geodesic paths between other actors in the network (i.e. more people depend on the actor to make connections to other people and therefore the actor has more power). The betweenness centrality C_B of an individual i, is then given by:

(2) $C_B(i) = \Sigma(S_{jk}(i)/S_{jk})$ for all j not equal to i not equal to k as an element of N

where: Sjk(i) denote the shortest path from j to k that some individuals i lie on.
Sjk denotes the number of shortest paths from j to k (IMAGES) (Amblard, 2001, p. 6)

Closeness centrality recognizes the distance of an actor to all others in the network by focusing on the geodesic distance from the actor to all other actors. High closeness actors have the shortest distances to all others and are in an excellent position to monitor information flow and are typically well positioned to be boundary spanners that connect their group to other clusters in the network. Reach is used as a measure of local access and represents the number of connections that can be reached in a number of steps. A high reach-in, where incoming flows are inbound, is known to have high authority where high reach-out connects to many others. Those actors with both high reach-in and high reach-out are known as a hub in the network. Peripheral actors are those actors with very low centrality scores, but are often connected to networks that are not currently being mapped making them very important for new information to the network. (Krebs, 2002) The Closeness Centrality $C_C(i)$ of an individual i becomes:

(3) $C_C(i) = N\text{-}1/\Sigma_{j=1 \text{ to } N}\, d(i,j)$

where: d(i,j) is the length of the minimum path linking individuals i and j (IMAGES) (Amblard, 2001, pp. 5- 6)

Network centralization represents the centrality of all of the nodes and can provide a great deal of information about the overall network structure. A very centralized network is dominated by one or a very few individuals, if these nodes are removed the network can quickly fragment into unconnected sub-networks. These highly centralized actors can become critical points of failure. Conversely, networks with low centrality scores are distributed and are not dominated by only a few, they have no “single point of failure” and are resilient to the loss of the actor. (Krebs, 2002)

Other network metrics include: structural equivalence which determines which actors (or nodes) play similar roles in the network; cluster analysis identifies cliques and other densely connected emergent clusters; structural holes show areas of no connections between nodes that could be used for advantage or opportunity; and external/internal

(E/I) ratios which find groups in the network that are open or closed to others. Small world metrics are used for nodes that are typically close together such as node clustering and short path lengths along the links between most pairs. (Krebs, 2002)

Clustering is an important phenomenon characterizing the deviation of real networks from the completely random entity-relationship model. The cluster coefficient is a quantitative measure of that tells us how much a node's collaborators are willing to collaborate with each other, and it represents the probability that two collaborators have worked together to produce products. The cluster coefficient (CC) is defined as follows: pick a node i that has links to k_i other nodes in the system. If these k_i nodes form a fully connected clique there are $k_i(k_i-1)/2$ links between them, but in reality we find much fewer. Denote N_i as the number of links that connect the selected k_i nodes to each other. The Cluster Coefficient CC for node i is then:

$$(4) \qquad CC_i \quad = \quad 2N_i/k_i(k_i-1)$$

The cluster coefficient for the whole network is obtained by averaging T_i over all of the nodes in the system. (Barabasi, 2001, pp. 1-14)

I. CHAPTER SUMMARY

SNA provides a set of effective methods and tools to measure, visualize, and analyze existing organizational knowledge flows. SNA can identify opportunities for targeted management initiatives to promote improved organizational network design, process improvements and the application of information technology based on quantifiable metrics and visualizations. The SNA metrics analyzed in this thesis include the group size, the number of isolates within the group, the remaining network size, the potential ties within the network, the actual ties within the network, the network density, the network cluster coefficient, the number of path lengths between the nodes in the network, and the average number of path lengths between the nodes within the network.

IV. RESEARCH METHODOLOGY

A. OVERVIEW

This section provides an introduction to the research methodology, the selection of the participants, the methods for data collection and data analysis.

B. PARTICIPANTS

Twenty-five personnel were identified who represented senior competency management and technical leadership personnel across the National Level 3 Materials Competency. These individuals included all of the MMB representatives as the National level 3 and level 4's, local site level 3's and 4's, and senior technical staff occupying national leadership positions. Individuals are distributed among the six competency sites and the six National level 4 Competencies and include six personnel from Patuxent River MD, three from Cherry Point NC, four from Jacksonville FL, two from North Island CA, four from Lakehurst NJ, and six from China Lake CA. These 25 individuals represented the six National Level 4 Competencies including: Metals/Ceramics, Industrial/Operational Chemicals, Nondestructive Inspection, Polymers/Composites, Analytical Chemistry and Testing, and Corrosion/Wear. All 25 participants were assigned attributes that reflected their level 3 or level 4 competency code alignment(s) and site locations as shown in Appendix C, the Survey Form of Appendix D, and as described in Appendix B. In a number of cases individuals were responsible for several level 4 competencies.

Each of the 25 surveyees hold designated leadership positions responsible for the flow of knowledge and expertise for each of the six survey questions pertaining to products across the lifecycle including science and technology, acquisition development, and in-service engineering; as well as leadership functions including business development, management and administration, and strategic planning. The sharing of knowledge and expertise across these subject areas is considered important to enable synergy across the full life cycle of operations and critical to improving the quality, efficiency, and effectiveness of the organization. For example, it is important that activities in science and technology are based on requirements from the acquisition and in-service communities, that science and technology innovations are transitioned to acquisition and in-service engineering applications, and that acquisition efforts leverage science and technology and address the requirements of in-service engineering.

C. DATA COLLECTION

A survey was used to provide both quantitative and qualitative feedback regarding the flow of knowledge and expertise throughout the National Level 3 Materials Competency. Participants were asked to identify the frequency which they shared their knowledge and expertise with others in the survey pool regarding three principle product oriented areas: science and technology, acquisition development, and in-service engineering; and three key leadership areas: business development, management and administrative, and strategic planning. Additionally, participants were asked to identify impediments to knowledge flow as well as recommendations in an open-ended manner. To accurately reflect the overall survey pool feedback, the survey tool was developed based on a series of best practices for effective survey design. The guidelines used were tailored to the specific needs of Social Network Analysis. A key guideline that allows a maximum of 20 minutes for survey completion was used which defined the length and scope of the instrument. (Cross, 2002, p. 107) Questions were developed which queried observable behavior rather than thoughts or motives. The survey instrument measured only behaviors that have a recognized link to the performance of the National Materials Competency.

The sections of the survey were designed to contain a similar number of items, and questions had a similar number of words to provide the highest probability of obtaining compatible survey responses across all of the questions. Questions regarding respondent demographics were not included in the survey instrument itself to avoid the appearance of invasiveness, improve response rates (since 100% is required for an effective SNA), and to invoke a positive response to the survey and its questions. The survey avoided the use of terms that may have a strong association and that might trigger biased responses. Each question was developed to focus on a specific topic so that two disconnected topics were not merged into a single question. A response scale was created to provide regularly spaced intervals, offering an odd number of options, and that asks respondents to estimate a frequency. A large body of research verifies that respondent's frequency estimations are usually very accurate and reliable. (Morrel-Samuels, 2002, pp. 111-118)

The survey was entered electronically as a matrix format in Microsoft Excel. The format was based on the InFlow survey format recommended at www.orgnet.com. The survey initially requested the respondent's name as required for effective SNA so that the network connections between the participants can be properly assigned. In Part I, the survey required respondents to specify the frequency of their flow of knowledge and expertise to other participants using the Microsoft Excel Data Validation Tool drop down menus. Part II required respondents to provide a narrative response to two open-ended questions regarding the impediments and recommendations to knowledge flow within the National Materials Competency.

Once the initial survey design was established, several prototype tests were conducted. The first was a self-test to demonstrate the utility and effectiveness of the software tools, the embedded macros, and the ability to transmit via web-based e-mail with full integrity. The second prototype test was conducted on three senior individuals who where not part of the survey. Survey feedback was used in the development and refinement of the survey instrument. Once the final draft was developed, it was distributed to the survey pool for final comments and questions. Group feedback was obtained regarding introductory and instructional comment length and composition, option selection presentation, data validation, question clarification, anonymity preference, qualitative and quantitative survey opportunities, and electronic-based distribution processes. This feedback was used to refine the final draft survey instrument to its final form. Refinements included: reduced introductory/orientation comments, refined question clarity and comprehensibility, and improvements in survey form design.

The survey was distributed electronically to all participants. A deadline was set of approximately one and one half weeks for completion with a Microsoft Outlook electronic flag follow-up notification and exclamation of importance. As survey responses were received they were reviewed for completeness and comprehension. If the survey was incomplete, the survey respondent was contacted, and the survey tool was returned for completion. Over 95% of the responses were received within the allotted time and eventually 100% were received for the data analysis.

D. DATA ANALYSIS

InFlow 3.0 student version software was used to conduct the social network analysis. An overview of InFlow 3.0 and its Windows-based features are available at www.orgnet.com. Data were input into the InFlow 3.0 software and InFlow's visualization scenarios were used to perform the SNA.

InFlow 3.0 is capable of mapping as well as measuring complex networks using standard Social Network Analysis measures and algorithms to evaluate individuals, groups or an entire network including: node and network centrality, cluster analysis, small-world metrics, structural equivalence, and internal and external ratios. The student version of InFlow 3.0 used for this study is limited to a maximum of 75 nodes and was easily affordable within the constraints of the study. (Krebs, 2001, 2002)

The InFlow 3.0 Software tool was designed to provide visualization scenarios for use in analyzing networks and developing network enhancements. For this study, visualization scenarios were developed to evaluate the National Materials Competency. It was found that several visualization features offered significant insight into Competency operations including existing structure networks, the "arrange" function using the Kamada-Kawai spring embedder algorithm as a minimum optimizer, the ability to visualize networks with flow directionality, and the ability to analyze various combinations of both questions and responses. Spring embedder models are used for drawing undirected graphs. Using an analogy to physics, nodes are treated as mutually repulsive charges and edges as springs connecting and attracting charges. Starting at an arbitrary placement of nodes, the algorithm iterates the system in discrete time steps by computing the forces (or link strengths) between the nodes and updating their position accordingly. The algorithm stops after a fixed number of iterations. The Kamada-Kawai model uses an optimal edge length approach that updates nodes sequentially by moving only one node at each step. The algorithm performs a gradient descent and converges deterministically to a local minimum for all nodes on a network providing a visualization of network interactions based on link strength and network connectivity. This powerful "Arrange" function in InFlow 3.0 allows for network visualizations based on network interactions versus official organizational hierarchy charts. (Frick, Ludwig, Mehldau; Kamada, Kawai 1989)

E. CHAPTER SUMMARY

The research methodology for this study was designed to identify specific areas of concentration and focus, identify the survey participants to provide maximum insight into Competency Operations, design an effective survey tool with high data integrity characteristics to provide valuable insight for an assessment of Competency operations, the formulation of recommendations, and the development of improvements. The survey was designed for ease of use across the geographically dispersed National Competency organization using a web-based approach with compatible and available software tools. The InFlow 3.0 SNA software was selected because of its high utility, affordability, technical support, and proven track record for SNA. The InFlow 3.0 tools provided all of the desired characteristics and measures of network performance, as well as the visualization tools for an effective SNA of the National Materials Competency organization.

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V. ANALYSIS AND RESULTS

A. INTRODUCTION

This section provides the analysis of the survey results for the national level 3 and national level 4 organizations. The section includes a discussion of the overall results including data analysis via SNA metrics, data visualizations using sociograms, a discussion addressing the application of the analysis to the research questions, and a summary which integrates the quantitative and qualitative analysis for both the national level 3 and level 4 organizations.

The survey generated substantial data regarding the networks of the National Materials Competency across the life cycle as well as technical and management responsibilities. InFlow 3.0 allowed the versatile application of available data to provide important insights into organizational operations. This included the ability to: easily allow the inclusion or exclusion of specified nodes or groups of nodes, selectively decide which responses to be included, and provided a series of design options to effectively portray data results. This was particularly useful when qualitatively evaluating sociogram visualizations of the entire National Materials Competency level 3 organization with a possible 600 single path length ties. In addition, all 25 individuals surveyed are responsible as the organization's leaders for disseminating knowledge and expertise across the National Level 3 Materials Competency in the areas of business development, management and administration, and strategic planning to facilitate the exchange of knowledge across the competency.

The results of the SNA were categorized into several key groupings: the national level 3 leadership organization as a whole which included all 25 representatives, and the six national level 4 organizations composed of aligned personnel. These groupings provided broad coverage of national competency operations to provide insight to existing social, intellectual and knowledge networks.

B. NATIONAL LEVEL 3 COMPETENCY SNA METRICS

1. Connectivity Among All National Level 3 Leaders

The National Materials Competency SNA result metrics are shown in Table 4 for both the National Level 3 Competency as a whole, and the National Level 4 Competencies. National Level 4 Competency data will be specifically discussed and analyzed in Sections D of Chapter V. From these data, the ranges of pertinent metrics describing the flow of knowledge and expertise within the National Materials Competency are provided. For the entire survey population of 25, the national level 3 leadership team data are presented as a summation of all responses and for each individual survey question.

Table 4 provides the overall group size, the number of isolates within the group, the network size of active participants, the potential number of ties between active participants, the network density which represents the number of actual ties divided by the number of potential ties, the network cluster coefficient as defined in Equation 4 of Section III which represents the probability that two collaborators have worked together to produce products, the number of path lengths required to reach each node in the scenario's knowledge flow network, and the average number of path lengths for the scenario's network.

For the National Level 3 All Responses scenario there is a ***group size*** of 25 participants. There are no ***isolates*** or individuals in this scenario that are not connected within the National Level 3 All Responses network. The ***network size*** of 25 represents the total number of participants involved in the network, excluding the isolates that exist within the group. The ***potential ties*** of 600 represents the total number of possible links within the network and was calculated by N*(N-1) or 25*24 = 600. The ***actual ties*** or network direct links represent the connections between nodes that exist in the network. For the National Level 3 All Responses scenario, a total of 240 actual single path length links were observed out of a possible 600 single path length links providing a ***network density*** of 40%. Conversely, 60% of the potential direct linkages to flow knowledge and expertise do not exist at any frequency. The ***cluster coefficient*** for the National Level 3 All Responses scenario was .66, or 66%. A fully connected cluster or clique is a set of nodes that are fully connected or linked. The cluster coefficient provides the average probability that collaborators are working together as a clique or cluster to produce products. The ***number of paths of length*** data provides the number of links or paths within the scenario's network to reach all of the other nodes. For the National Level 3 All Responses network there exists 240 single path lengths links, 920 double path length links, and 368 triple path length links. The ***average path length*** between all of the nodes for this network is 2.08, indicating that on average it takes 2.08 links to connect all of the nodes in this network. The average path length provides a measure of organizational connectivity across the entire National Materials Competency leadership team. For the National Level 3 All Responses network the maximum number of path lengths is 3, showing that each leader is connected to all others within 3 network links for knowledge flow. The fewer the number of path lengths in a network, the more interconnected the network is, the more direct knowledge flow occurs, and the more the social network resembles a clique or cluster. However, if all links were included in a Path Length of 1, it would be interpreted that all nodes were connected by a single link to each other. This would not be desirable for a large organization since there are external connections, outside the scope of this effort, that are valuable, necessary and require time to develop and nurture. At the other extreme, if a node required in this network required a large number path lengths (limited to 24) to flow knowledge, it would not be an efficient or effective social network, and knowledge flow would be hampered. Balancing internal organizational cohesion with external brokerage to other groups of opportunity or value is a key consideration and judgment for optimum performance. The National Level 3 All Responses scenario will naturally have the highest number of direct single path links because it is the summary of all responses for all nodes. This scenario also has the fewest number of path lengths for all the nodes to access one another.

2. National Level 3 Leader Connectivity Related to Products and Processes

Table 4 provides the comparison of potential ties to actual ties for each individual question for all responses across the National Level 3 Materials Competency. From this data we can see an emphasis in in-service engineering (density = 30%), as well as management and administration (density = 27%) respectively, followed closely by science and technology (density = 26%). Table 4 also provides the density, cluster coefficient and average path length for each question. The cluster coefficients for these individual questions indicate that the group as a whole does represent a clique most strongly in the areas of in-service engineering, and management and administration. The average path length is greatest for acquisition engineering at 2.64 with the lowest for business development at 2.24. This indicates that individuals across the National Level 3 Competency engaged in acquisition engineering, are on average more distributed, less active in networking and sharing knowledge, and less interconnected while the individuals involved in business development are working closer together, and sharing knowledge as a community. Knowledge flow in the area of in-service engineering appears as the greatest based on the highest number of actual ties, the highest density of flows, and the highest cluster coefficient as a community which is tied with management and administration. Knowledge flow in acquisition engineering represents the observed minimum interconnectedness, based on the lowest number of actual ties, the lowest density, the lowest cluster coefficient, the highest path length of 6, and the highest average path length of 2.64.

Figure 5 provides the percent distribution of the National Level 3 Materials Competency actual ties which provide an indication of relative knowledge flow connectivity in each survey question area for comparison. The most actual ties across the network occur in in-service engineering at 20% followed by management and administrative at 18%, science and technology at 17%, strategic planning at 16%, business development at 15%, and acquisition development at 14% respectively. This is a relative comparison of the level of actual network activity within these product and process areas across the leadership team. The difference between the maximum number of network links for in-service engineering of 180 and the minimum number of network links for acquisition engineering of 132 is 48 network links. This represents a 12.4% difference within the 600 potential links or an increase of 27% over the minimum number of network linkages for identified products and processes. This indicates the relative range of knowledge flow across the National Materials Competency network activity.

Community	Group Size	Isolates	Network Size	Potential Ties in Network	Actual Ties in Network	Network Density	Network Cluster Coefficient	Number of Paths of Length: 1	2	3	4	5	6	Average Path Length
National Level 3														
National Level 3 All Responses	25	0	25	600	240	0.40	0.66	240	920	368	0	0	0	2.08
Science and Technology	25	0	25	600	158	0.26	0.58	158	411	405	193	28	0	2.60
Acquisition Engineering	25	0	25	600	132	0.22	0.53	132	339	310	104	45	21	2.64
In-Service Engineering	25	0	25	600	180	0.30	0.61	180	574	413	86	0	0	2.32
Business Development	25	0	25	600	138	0.23	0.57	138	355	224	51	0	0	2.24
Management & Administrative	25	0	25	600	164	0.27	0.62	164	537	440	121	0	0	2.41
Strategic Planning	25	0	25	600	142	0.24	0.60	142	405	321	116	0	0	2.42
National Level 4 Leaders - All Responses/All Questions Summary														
Metals/Ceramics	5	0	5	20	5	0.25	0	5	2	0	0	0	0	1.29
Industrial/Operational Chemicals	6	0	6	30	13	0.43	0.69	13	13	6	0	0	0	1.78
Nondestructive Inspection	5	1	4	12	4	0.33	0	4	2	0	0	0	0	1.33
Polymers/Composites	6	0	6	30	10	0.33	0.44	10	8	2	0	0	0	1.60
Analytical Chemistry & Test	5	0	5	20	5	0.25	0	5	5	0	0	0	0	1.50
Corrosion/Wear	6	1	5	20	5	0.25	0	5	4	1	0	0	0	1.60

Table 4. Social Network Analysis Summary Metrics

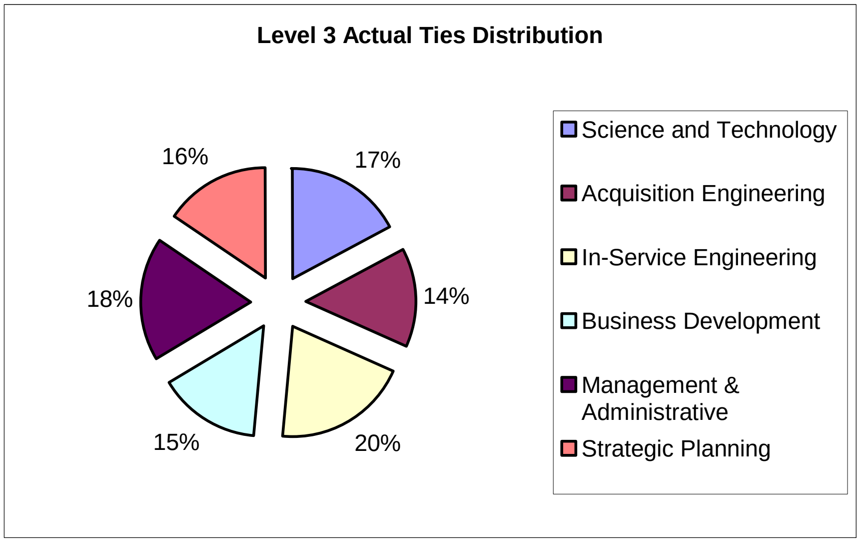

Figure 5. Level 3 Actual Ties Distribution

C. NATIONAL LEVEL 3 COMPETENCY SOCIOGRAMS AND VISUALIZATIONS

The National Level 3 Competency leadership organization is depicted visually in Figure 6 as the Baseline Structural Layout where each node is grouped by their resident location. The Baseline Structural Layout is used as the hierarchical network diagram depiction in InFlow 3.0, and is used for comparison with the Kamada-Kawai algorithm sociograms to evaluate the emergent networks. The Baseline Structural Layout groups the survey participants into clusters based on site location with the Site Leadership depicted at the top of each cluster. The 25 National Materials Competency leadership personnel surveyed are depicted by numbered nodes. Specific competency assignments for each node are provided in Appendix C. InFlow 3.0 uses the Baseline Structural Layout as the initial sociogram structure. Network flows based on the survey responses have been developed and displayed for each scenario in this form. The Kamada-Kawai algorithm uses the Baseline Structural Layout as its starting position for the nodes in the scenario, and uses the scenario's knowledge flow frequencies across the nodes to develop the emergent network. The Kamada-Kawai algorithm will cluster nodes with high frequency and disperse nodes with low or no frequency in an integrated fashion across the scenario's nodes. InFlow 3.0 was set to conduct 200 algorithm iterations for each scenario. This setting was shown to produce highly optimum and stable results in minimal time based on a series of experimental scenario observations.   The Kamada-Kawai algorithm was chosen to produce consistent and reliable results for visualization analysis. InFlow 3.0 offers significant flexibility for developing social network scenarios and visualizations. The results from InFlow 3.0 show linkages between nodes as depicted by point-to-point arrows as connections, which show the directionality of knowledge flow between leaders or nodes. The thickness of the arrow lines is dependent on the frequency of the knowledge flows; the thicker the line the more frequent the flow of knowledge, the thinner the line the less frequent. If two-way flows exist arrows from each node to the other will be displayed, and the line thickness will reflect the additive frequency of knowledge flow. If no line exists there exists no flow of knowledge within that particular scenario.

Baseline Structural Layout

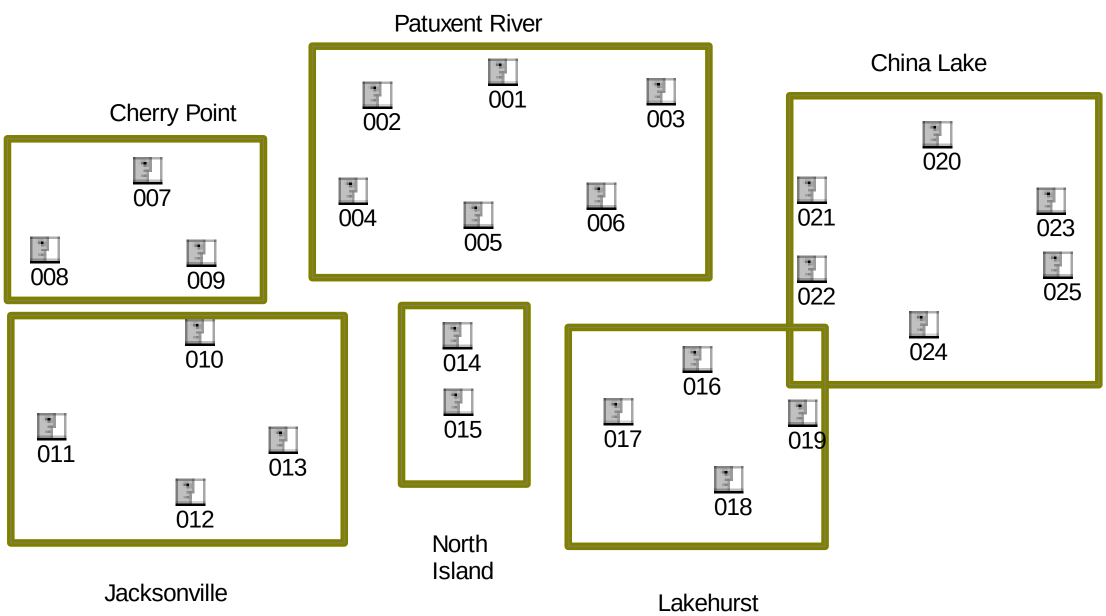

Figure 6. Baseline Structural Layout for InFlow 3.0 Visualizations

Based on the Baseline Structural Layout from Figure 6, Figure 7 depicts the entire National Level 3 Materials Competency leadership team for all questions and all responses with one and two-way links, and represents the data in Table 4 for National Level 3 All Responses. This is a top level organizational depiction which summarizes all of the survey data collected across the National Level 3 Materials Competency. In subsequent visualizations or sociograms as well as discussions in this chapter, we will retain the basic form of the node distribution, unless the visualization is in the arranged form. The Baseline Structural Layout will be decomposed into its various components based on the scenario of interest, and the analysis of the individual nodes and networks that comprise this summary visualization will become much clearer.

The National Level 3 Materials Competency shown in Figure 7 is highly cluttered as expected based on the number of 240 actual ties, and based on the thickest lines or most frequent knowledge flows, it shows overall clustering within the local sites when all questions are included. This representation shows that the most frequent knowledge flows generally exist within the six individual sites versus between these sites. It is important to view both the links within the site clusters as shown in the Baseline Structural Layout, as well as the links between the local site clusters.

Many of the links between the site clusters are one-way directional flow. Typically, one-way flow is not considered to substantially contribute to intellectual capital because of the lack of knowledge exchange and combination. Two-way flow is more indicative of an exchange of knowledge that results in increased intellectual capital within an organization or group.

Figure 8 analyzes the two-way symmetric ties only. This represents the two-way knowledge flow indicative of the level of development of intellectual capital as a result of exchange and combination.

Figure 9 provides the same scenario in the "arranged" view using the Kamada-Kawai spring embedder algorithm which highlights the form of the emergent knowledge network across the National Level 3 Competency. As shown in Figure 9, this algorithm disperses infrequent and non-existent interactive nodes, and clusters frequent interactive knowledge flow nodes. The strongest two-way flow is occurring within the local sites and although networks exist, they are generally weak across all of the sites. Node 020 is a management concern because it represents a potential single "bottleneck" node connecting China Lake with the rest of the national sites regarding knowledge flow. Also, other members of China Lake do not have two-way flow outside their local site as shown by their relative dispersion from the center indicating a lack of connection to the rest of organization, which is a strong concern. It is anticipated that these individuals have a great deal of knowledge to share and there are opportunities for increased intellectual capital at China Lake by exchanging and combining knowledge from other sites. The clustering of Patuxent River MD, Cherry Point NC and North Island CA indicates strong flows of knowledge between those sites. However, China Lake CA and Lakehurst NJ are relatively isolated from the rest of the organization. Node 015 from North Island is also a concern because of the lack of flow to anyone in the network other than node 014, his supervisor. Node 002 is infrequently linked to other members at Patuxent River, and does not have symmetric links outside Patuxent River MD which causes a concern as well. Figure 9 is particularly important as we focus to improve the knowledge flow across the national level 3 leadership team by increasing two-way knowledge flow, facilitating the development of important connections which can reduce the average path length across the entire network. To better visualize this appearance, InFlow 3.0 provides the capability to select or filter the frequencies desired.

Figure 10 provides a sociogram for survey frequency selections 3 to 5 pertaining to monthly, weekly and daily interactions combined. This highlights the moderate to strongest linkages across the span of all questions, both one and two-way knowledge flows. Clearly, the effects of geographic dispersion come into play as we can see strong linkages that exist at the local site level replicating much of the structural clustering seen in Figure 11.

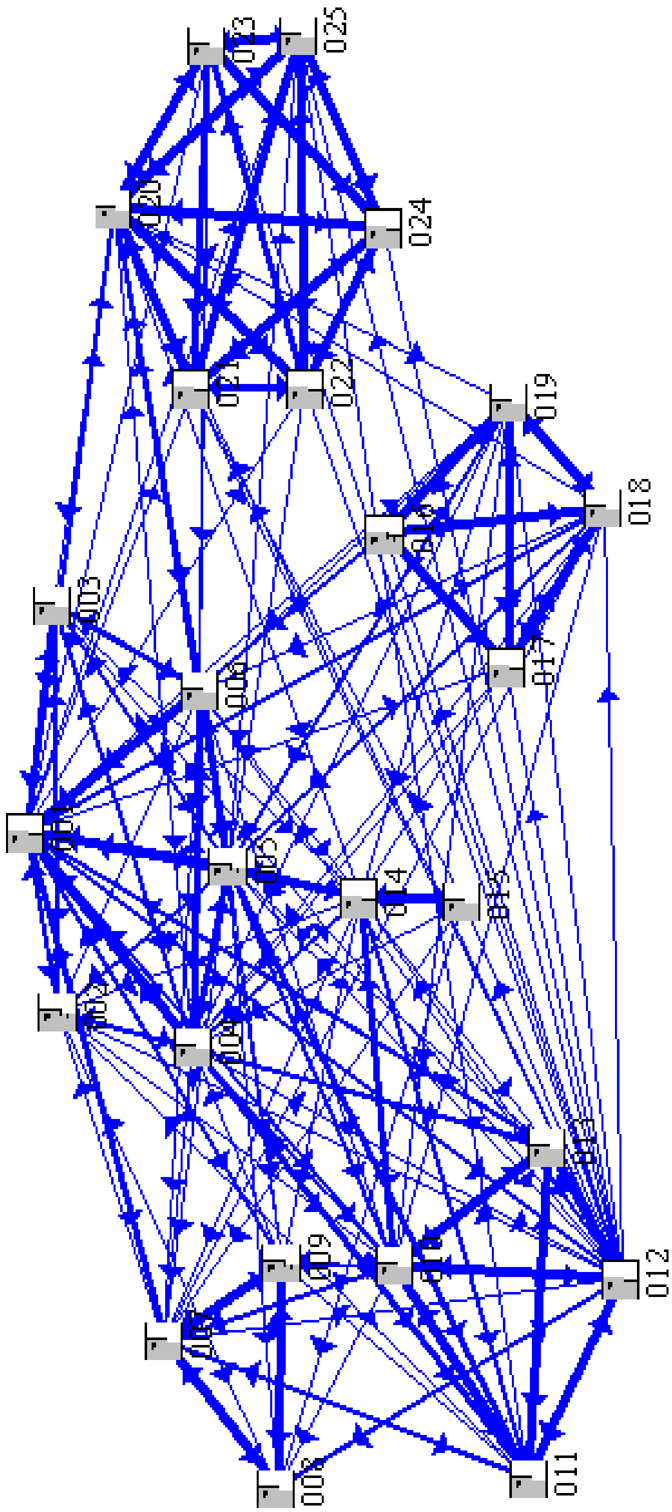

Figure 7. National Level 3 All Questions/All Responses with Frequency Weighting and One or Two-way Directionality

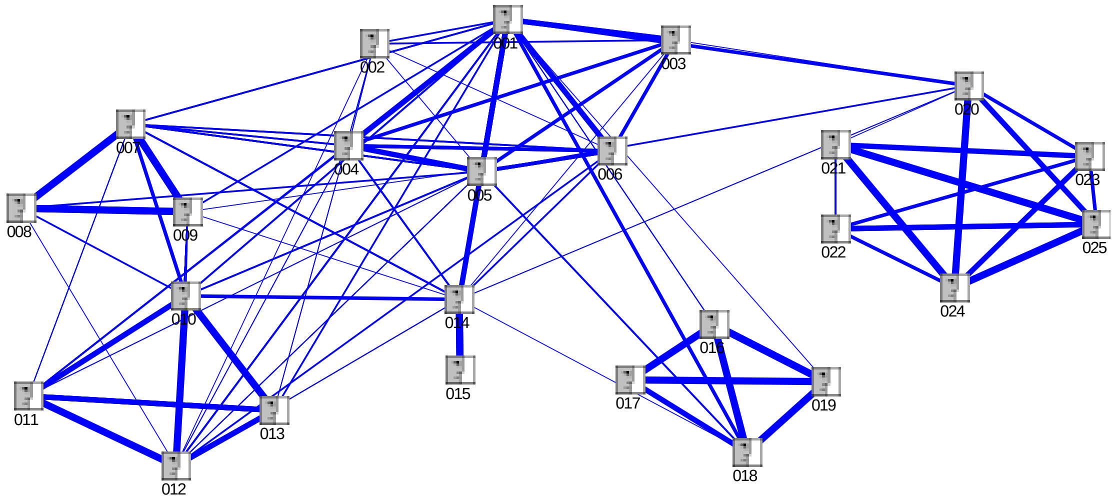

Figure 8. National Level 3 All Question/All Responses with Frequency Weighting and

Symmetric Ties Only

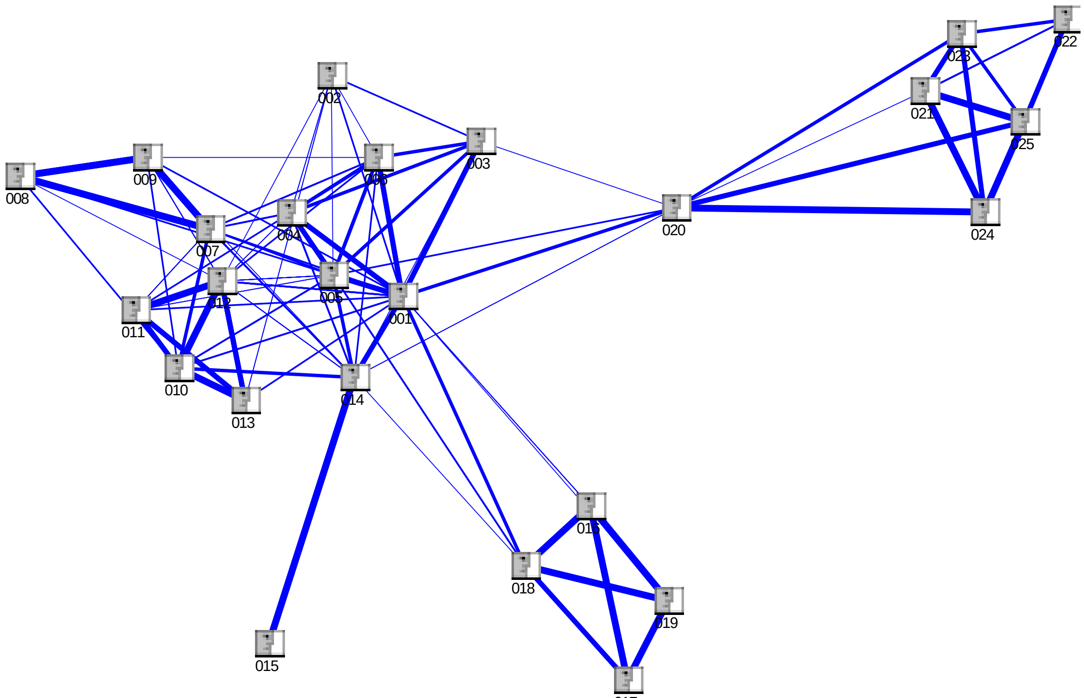

Figure 9. National Level 3 All Questions/All Responses with Frequency Weighting and

Symmetric Ties Only Arranged Emergent Structure

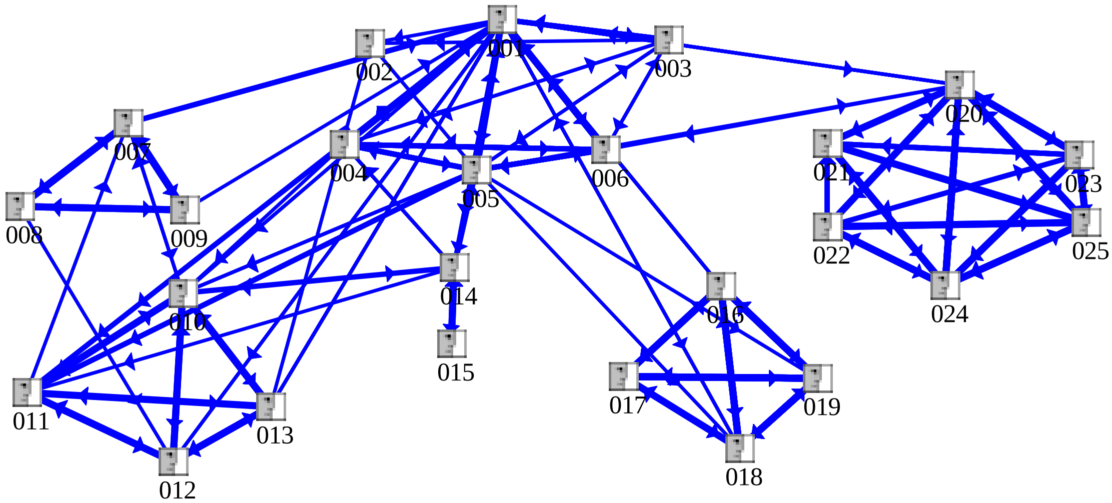

Figure 10. National Level 3 All Questions/Responses 3 to 5 Frequency Weighting, One and Two-way Directionality

Figure 10 shows node 020 controlling a majority of external flows of knowledge and expertise outside of the local site. Node 015 possesses a strong singular linkage with node 014, and is highly dependent on node 014 for external connectivity. Seven nodes; 015, 017, 021, 022, 023, 024, and 025 have no external site flows of knowledge with the rest of the National Level 3 Materials Competency in any direction at the monthly, weekly are daily frequency. Five nodes; 003, 008, 009, 016, and 019 have only one external site flow of knowledge in any direction at the monthly, weekly and daily frequency.

Similarly, an analysis of National Materials Competency Level 3 leadership team yields Figure 11 as the emergent structure using the "arrange" function of InFlow3.0. The emergent structure highlights the central and outlying actors in the network taking frequency weighting into account. The weakly linked nodes 002 and 003 have moved out of the center, while the strong linkage with the Jacksonville site becomes prevalent. The increased distance of node 020 as well as nodes 021, 022, 023, 024 and 025 indicates a relatively weak or infrequent linkage with the rest of the network structure.

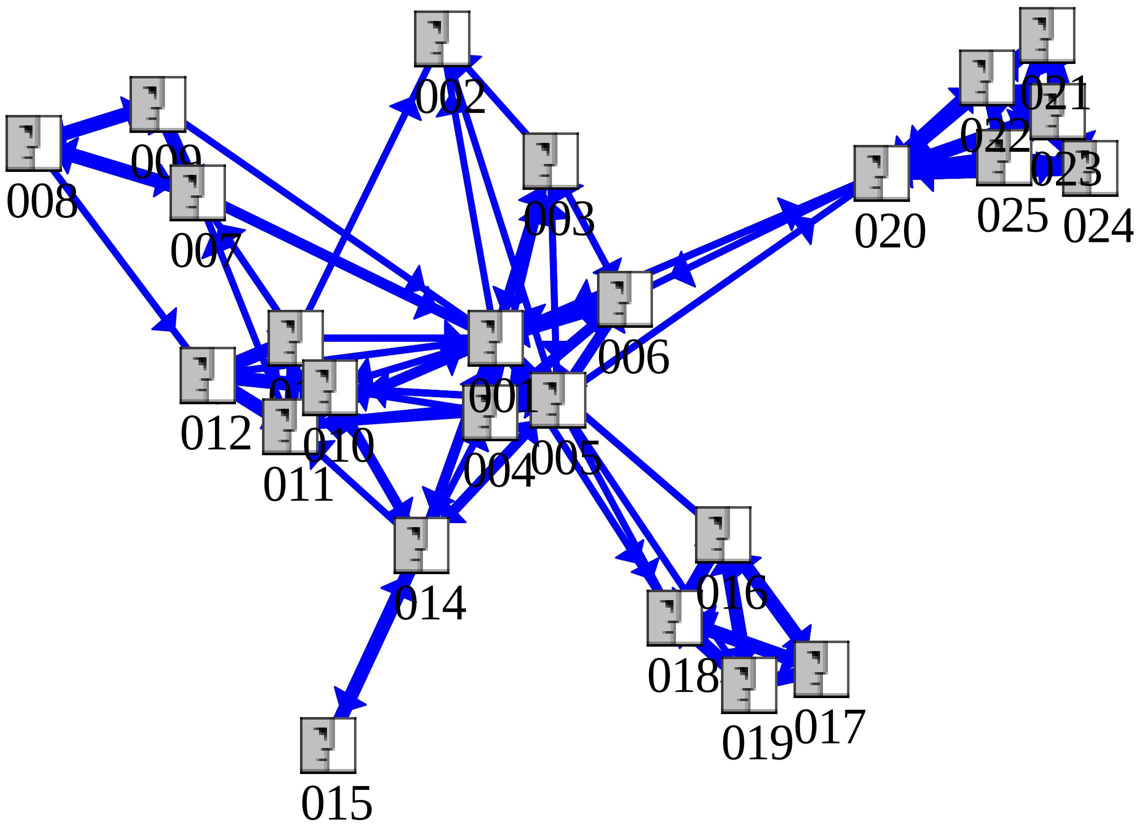

Figure 11. National Level 3 All Questions/Responses 3 to 5 with Frequency Weighting, One and Two-way Directionality "Arranged" Emergent Structure

Figures 7-11 indicates the potential for significant impact to the National Materials Competency mission. The relatively low combination and exchange of knowledge as a result of symmetric ties with China Lake, Lakehurst as well as North Island Level 4 leadership indicates that improved organization development of intellectual capital and personnel empowerment could be achieved in the areas of weapons, aircraft launch and recovery equipment, support equipment, as well as in-service engineering for North Island cognizant systems. In addition, the National Materials Competency is not obtaining the available benefits of knowledge flow from these three sites to impact the six critical question areas. Appendix E provides supplemental results and analysis for the National Level 3 Materials Competency, including visualizations for each of the individual survey questions.

D. NATIONAL LEVEL 4 COMPETENCY SNA METRICS

The national level 4 leadership team data results are provided in Table 4 and can be compared to the overall national level 3 responses. Figure 12 compares the potential ties to the actual ties for networks within each level 4 leadership team. As shown, the National Industrial/Operational Chemicals Level 4 Competency had the highest number of actual ties while the National Nondestructive Evaluation Level 4 Competency had the least.

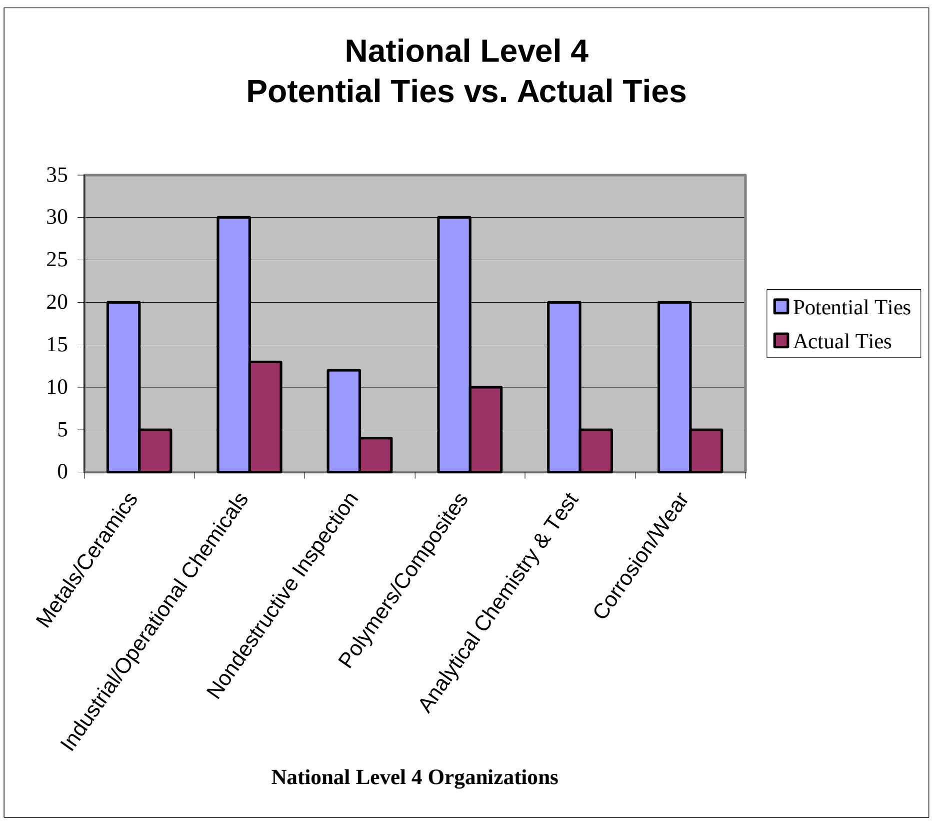

Figure 12. National Level 4 Potential Ties vs. Actual Ties

Figure 13 provides the individual network densities. Industrial and Operational Chemicals Level 4 Competency shows the greatest level of direct connections at 43%, and the National Level 4 Metals/Ceramics, Analytical Chemistry and Test, and Corrosion/Wear Competencies at the lowest with 25%. The Industrial/Operational Chemicals Competency also ranked with the highest cluster coefficient of .69, indicating a relatively more connected group or clique, but relying on the maximum average path length of 1.78 compared to the minimum of 1.29 for the National Level 4 Metals/Ceramics Competency. Two isolates, or leaders who were not part of the network were identified within the National Level 4 organizations. One isolate was identified within the National Level 4 Nondestructive Inspection Competency and one was identified within the Corrosion/Wear Competency. This indicates a lack of knowledge flow within these groups to the single leader or node in the group.

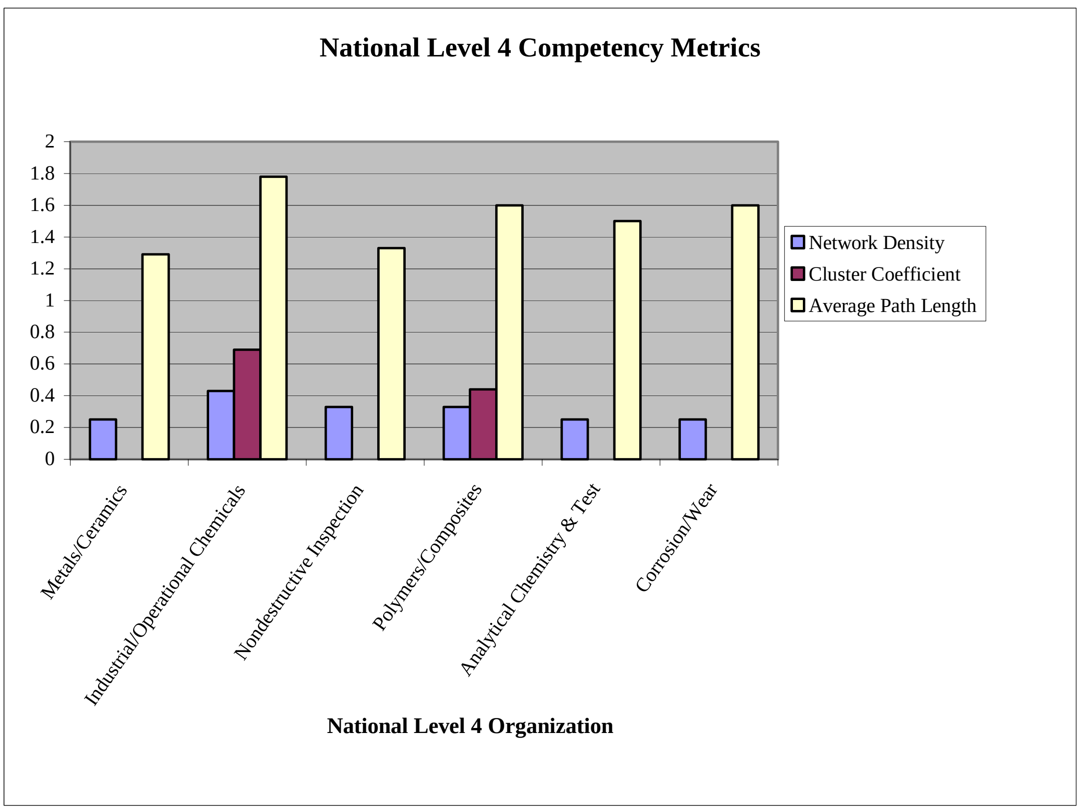

Figure 13. National Level 4 Leadership Team Metrics

E. NATIONAL LEVEL 4 COMPETENCY SOCIOGRAMS AND VISUALIZATIONS

The National Metals/Ceramics Level 4 Competency was evaluated on the basis of all responses and based on each individual survey question to evaluate the level of connectivity. Figure 14 represents the selected Metals/Ceramics designated nodes of the Baseline Structural Layout from Figure 6. Figure 14 provides a sum of all responses for the Baseline Structural Layout for Metals/Ceramics, while Figure 15 represents the emergent structure developed from the Baseline Structural Layout for all questions and all responses. It should be noted that no node for the National Metals/Ceramics Level 4 Competency was identified at Cherry Point. In general, the overall flow of knowledge and expertise across the National Metals/Ceramics Level 4 Competency leadership is relatively low. Node 004, the Metals/Ceramics National Level 4 Competency Leader, is central to the flow of knowledge, however, the linkage to node 021 requires two path links and the directionality of flow is greater incoming to node 004 than outgoing indicating a lack of external communications from the leadership. Network density is only 25% for the National Level 4 Metals/Ceramics Competency for all responses. Additional results and analysis are provided in Appendix F for the six survey questions.

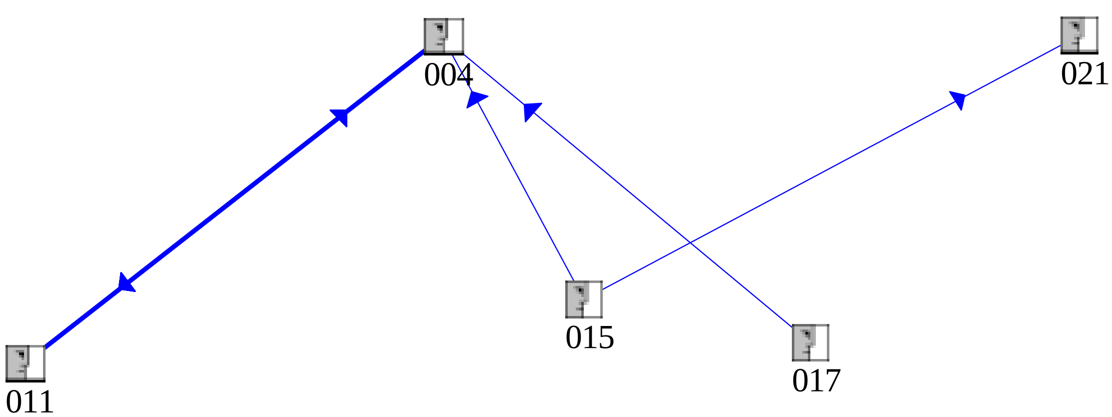

Figure 14. National Level 4 Metals/Ceramics Competency All Responses

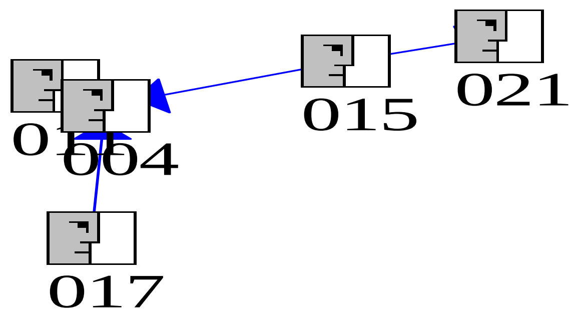

Figure 15. National Level 4 Metals/Ceramics All Responses “Arranged”

The National Level 4 Competency for Industrial and Operational Chemicals shows a high degree of connectivity across sites based on the interconnectedness across all sites with a high proportion of two-way flow and at least one way knowledge flow for all responses. Figures 16 and 17 show the high centrality of nodes 005 and 012 in the network. Five of the nine linkages are shown as only one-way knowledge flow. Sociograms for the National Level 4 Industrial and Operational Chemical Competency show a relatively high degree of connectivity across the life cycle and product and organizational functions. No isolates exist in this National Level 4 Competency. Additional results and analysis are provided in Appendix F for the six survey questions.

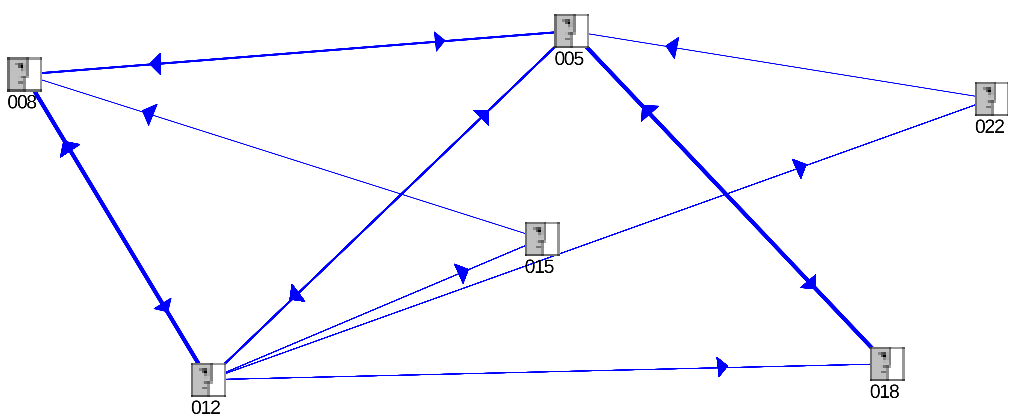

Figure 16. National Level 4 Industrial/Operational Chemicals All Responses

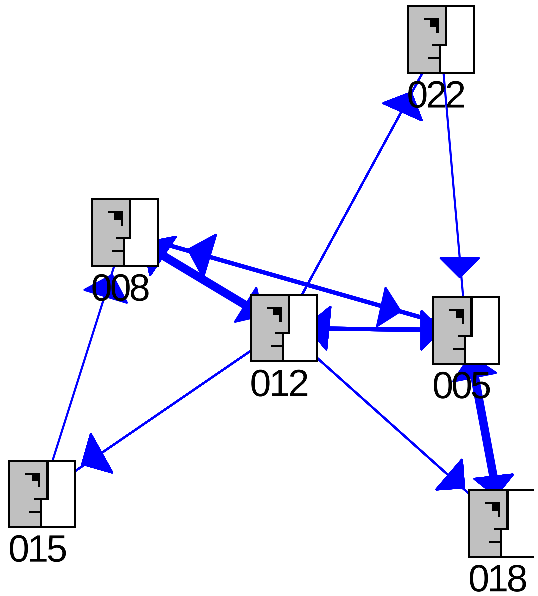

Figure 17. National Level 4 Industrial/Operational Chemicals All Responses “Arranged”

The National Level 4 Nondestructive Inspection Competency leadership is shown summarized in Figures 18 and 19. These diagrams indicate a star topology or hub centralized at node 004. No flow of knowledge and expertise is observed between the other site level 4 leaders. Also, node 008 is an isolate within the group that is not an integral part of the National Level 4 Nondestructive Inspection network, and therefore the benefits of flowing knowledge and expertise to and from node 008 are not being realized. Two of the three links within the network are only one-way links to the National Level 4 Competency leader, indicating that the exchange and combination of knowledge and expertise is not occurring leading to sub optimum development of intellectual capital within the Level 4 Nondestructive Inspection Competency. Additional results and analysis are provided in Appendix F for the six survey questions. Generally, very little knowledge flow exists for science and technology, in-service engineering, business development, and strategic planning.

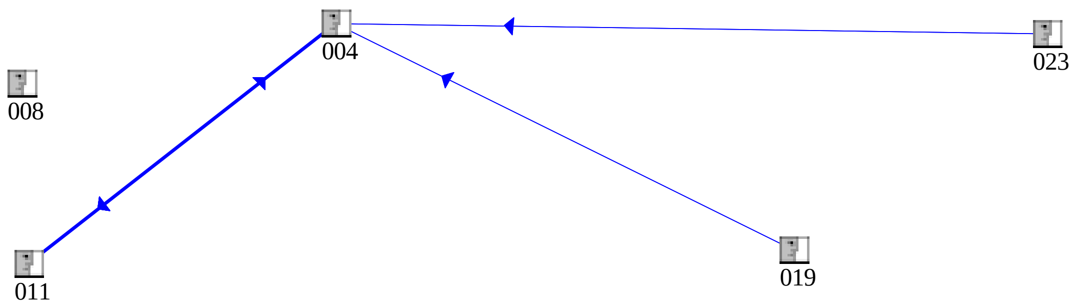

Figure 18. National Level 4 Nondestructive Inspection All Responses

Figure 19. National Level 4 Nondestructive Inspection All Responses "Arranged"

The National Level 4 Polymers and Composites Competency shown in Figures 20 and 21 indicate a relatively high degree of one-way connectivity and two-way knowledge flow across the sites with no all-responses isolates. Node 012, which is not the National Level 4 Competency leader, appears to be most central within the Competency as shown in Figures 20 and 21. Additional results and analysis are provided in Appendix F for the six survey questions. All specific question plots have a similar layout except for management and administration, where node 018 is linked in one-way flow to the National Level 4 Competency Leader.

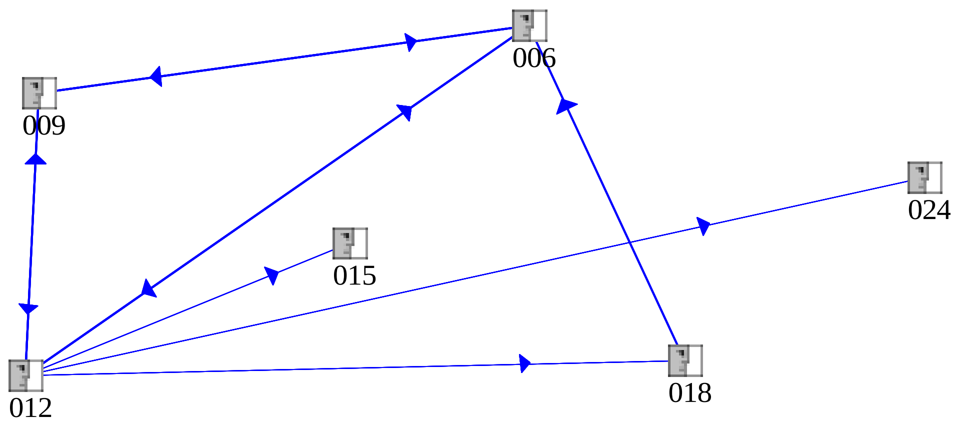

Figure 20. National Level 4 Polymers/Composites All Responses

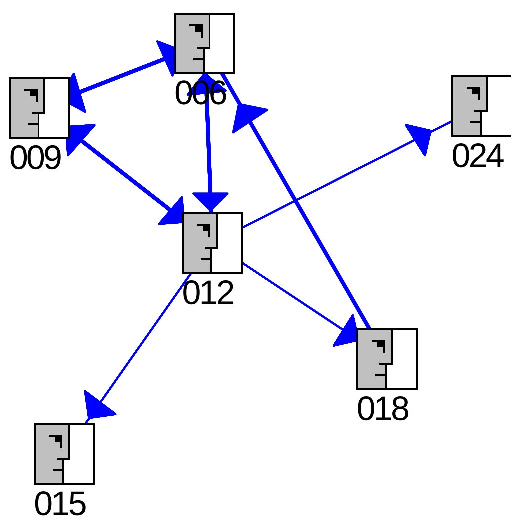

Figure 21. National Level 4 Polymers/Composites All Responses "Arranged"

The National Level 4 Analytical Chemistry and Test Competency is shown in Figures 22 and 23. A classic star topology is evident and the arranged nodes in Figure 23 show the center of activity at node 005 is the National Level 4 Competency Leader. The Figures indicate a high degree of isolates in the charts especially at China Lake, Jacksonville and Lakehurst. Significant improvements in cross-site collaboration are required to flow knowledge and expertise across the enterprise. Node 005 has high power under these circumstances and presents a risk should that node no longer be available. In no cases are sites connected to sites other than Patuxent River. Additional results and analysis are provided in Appendix F for the six survey questions. There are significant network weaknesses in business development and strategic planning as evidenced by the lack of knowledge flow links.

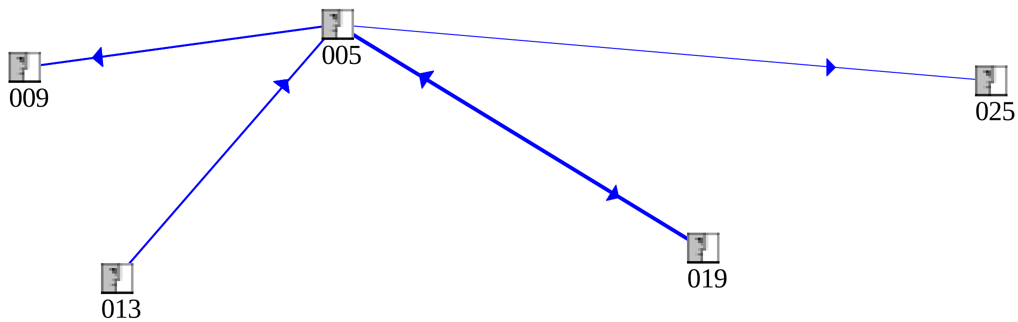

Figure 22. National Level 4 Analytical Chemistry and Test All Responses

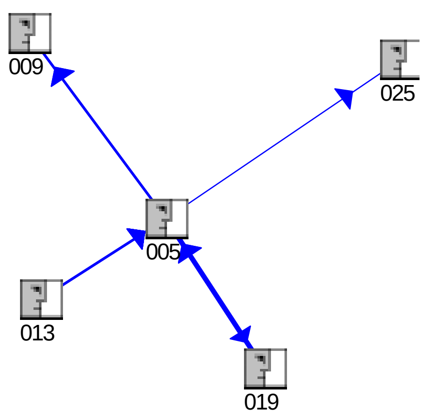

Figure 23. National Level 4 Analytical Chemistry and Test All Responses "Arranged"

The National Level 4 Corrosion and Wear Competency shows very weak linkages across all questions as shown in Figures 24 and 25. Node 017 is an isolate for all responses. Three of the four links are one-way links with node 005 as the center of interchange as shown in Figure 24. Additional results and analysis are provided in

Appendix F for the six survey questions. No interactions exist at all for acquisition, business development, or management and administrative.

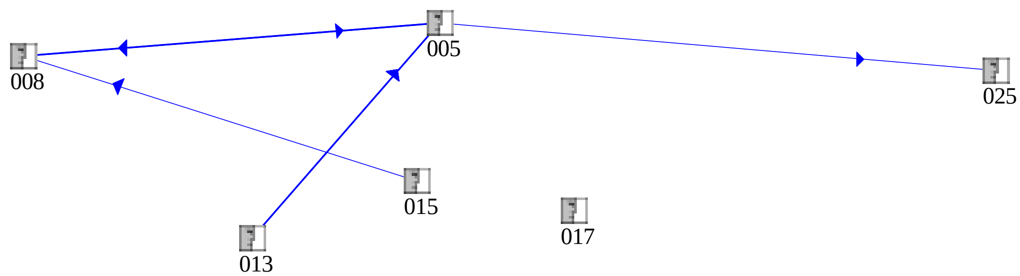

Figure 24. National Level 4 Corrosion and Wear All Responses

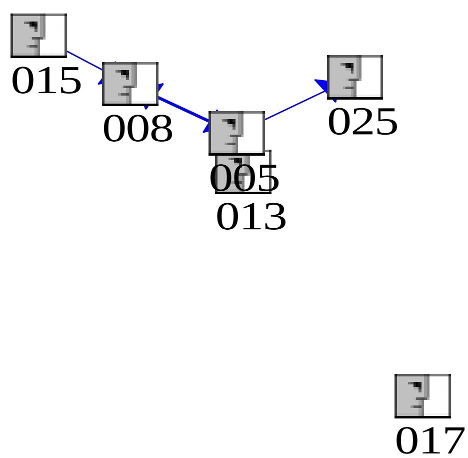

Figure 25. National Level 4 Corrosion and Wear All Responses "Arranged"

F. OPEN-ENDED SURVEY RESPONSES

1. Notable Impediments to Knowledge Flow

The SNA survey included an opportunity for those surveyed to identify notable impediments to improving the flow of knowledge and expertise across the National Materials Competency. The following survey responses can be summarized into two major categories:

Physical/Organizational Constraints

- Time Availability
- Resources Constraints
- Lack of Cross-site Video-teleconference Capability
- Competition for Resources
- Geographically Dispersion
- Structural Difference: Hiring, Awards, Promotions, Funding, Code Assignments, Performance Metrics
- Infrequency of Management-level Interactions
- Inadequate Opportunities for Formal or Informal Exchange

Social Constraints

- Inadequate Knowledge and Awareness of Individual and Site Skills and Capabilities
- Competition for Resources
- Resistance to Change
- Lack of Trust and Respect
- Inadequate Awareness of Lessons Learned
- Not Knowing Others: Expertise, Capabilities, Programs
- Reluctance to Problem Solving by "Committee"
- Inadequate Cross-site Support, Endorsement and Acknowledgement

These impediments offer opportunities for management attention to help improve the development of social capital, intellectual capital and knowledge flow across the National Materials Competency. They provide an opportunity for proactive correction that will enhance competency communications and the flow of knowledge and expertise. These impediments provide a basis for Materials Management Board action, as well as foster improved organizational insight throughout the NAVAIR to help address pertinent social, structural and cultural challenges.

2. Recommendations to Improve Knowledge Flow

In addition to identifying the impediments, the survey instrument requested recommendations that could be used to facilitate the flow of knowledge and expertise across the National Materials Competency. The following provides survey responses summarized into three major groupings of recommendations:

Formal and Informal Relationship Building

- Create Cross-site Enterprise Teams
- Develop More Cross-site Cooperative Programs
- Provide Cross-site Training
- Increase Rotational Assignments between Sites
- Reduce e-Mail, Emphasize Phone Conversations
- Increase One-to-One Interaction
- Educate Organization on Competency Charter, and Competency Operating Guide (COG)
- Increase Formal/Informal Interactions on Technical Issues and Policies
- Engage Working Level on National Projects
- Develop Friendships Throughout National Organization
- Improve National Competency Training
- Continue National Air Vehicle Conference Involvement
- Improve Sharing of National Competency Capabilities

Organizational Processes and Policies Development

- Establish Common Organizational Codes
- Highlight Best Examples of Teamwork
- Seek Level 2 Organizational Buy-in for Competency Operating Guide (COG)
- Establish National "Common" Goals
- Obtain National Level 2 Endorsements for COG

- Develop a Resume Directory
- Post National Competency Requirement, Needs, and Goals
- Improve Definition of Roles and Responsibilities

Technology Enabling Enhancements

- Provide Enhanced Collaborative Environments
- Schedule Regular, Planned and Coordinated Video-teleconferences
- Implement the Aerospace Materials Technology Consortium Tele-collaborative Web Portal
- Conduct National Level 4 Meetings (video teleconference enhanced)
- Create Common Databases
- Hold Regular MMB Meetings (site and video teleconference)
- Establish a National Web-site

Focusing on these areas will help to augment the resolution of impediments to knowledge flow and help further build social capital, enhance intellectual capital and facilitate the effective flow of National Materials Competency knowledge and expertise. They form an action item list for our MMB future activities. Given time for sufficient implementation of organizational initiatives, SNA can be used to evaluate the value of any changes to improving the efficacy of the National Materials Competency now that a baseline has been established.

G. DISCUSSION

This SNA captured the flow of knowledge and expertise across the full spectrum of organizational product-oriented and leadership-driven activities. These activities included the evolution of products from: science and technology, acquisition engineering and development, and in-service engineering. Activities evaluated from a leadership perspective included business development, management and administration, and strategic planning. By evaluating the frequency of leadership and senior technical personnel communications across sites, and grouped in relevant ways, SNA was able to uncover and characterize the existence of structural holes, their location, and where an overall lack of cohesion exists within the network.

The SNA captured the extent that each site and each member currently contributes, participates, and collaborates in key national competency products and processes across the lifecycle by developing both individual and group metrics, as well as network visualizations. Clear distinctions were made between individuals, sites, national level 4 competencies, and key products and processes. Strong as well as weak linkages were highlighted during the SNA and were best examined through the use of the Kamada-Kawai spring embedder "arrange" minimum optimize function. The level of contribution, participation and collaboration observed correlated well to the primary mission of each site.

The patterns of relationships were identified among the National Materials Competency leadership and senior technical specialists. These patterns were the result of evaluations using the baseline structural layout as well as the "arrange" function. The topologies highlighted as a result of the "arrange" function included star patterns or hubs, cliques, and myriad unique patterns reflecting the frequency weightings and inter- and intra-site collaborations.

The SNA provided insight into how the efficacy of the NAVAIR Materials Division National Materials Competency can be improved by enhancing the flows of knowledge and expertise. Individuals and groups that showed a low degree of connectivity, as well as those individuals in positions of significant network power that bottleneck the flow of knowledge and expertise, are now identified directly for management improvement. Individuals who belong to the same Organizational Breakdown Structure appear to have varying levels of cohesion within their national leadership organization. The SNA assessed that the highest frequency of knowledge and expertise flow occurred at the local site level. Linkages external to the local sites were generally less frequent or in some cases non-existent. The SNA results identified one-way linkages. Extant research indicates that two-way flow provides the basis for knowledge creation.

Across the sites, weak interactions generally existed in the product area for science and technology, and acquisition, and were highest for in-service engineering. Within in-service engineering, opportunities are available for stronger relationships where distances are greatest on the “arranged” visualizations, for example between: Cherry Point and China Lake, Cherry Point and Lakehurst, Cherry Point and North Island, China Lake and Lakehurst, Patuxent River and China Lake, and North and China Lake. To provide increased cohesion within the National Materials Competency, reduce the reach, and improve the cross-site clustering these linkages need to be strengthened. The weakest flow of knowledge and expertise across the leadership functions occurred in business development and strategic planning. Given the strong organizational emphasis on critical flight safety tactical issues, and the need for strong direct current year financial performance, it was anticipated that these indirect and longer term strategic functions would represent the weakest networks. The SNA highlights that the business development and strategic planning that does occur, occurs most frequently at the individual sites where the local benefits vice national benefits are more apparent. It is anticipated that the incorporation of national performance metrics would help improve overall National Materials Competency performance and efficiency.

Generally, the topologies and frequency of knowledge and expertise flow across the Organizational Breakdown Structure elements displayed relatively weak interactions among the designated leadership. Star topologies to the National Level 4 Competency leaders indicate poor interconnectivity cross-site for those sites other than Patuxent River. In some cases, no individual leadership connectivity was evident within the National Competency Level 4 organizations. The National Level 4 Competencies for Industrial/Operational Chemicals, and Polymers and Composites had the strongest flow of knowledge and expertise.

VI. CONCLUSIONS, IMPLICATIONS, LIMITATIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The purpose of this thesis was to provide an assessment of an existing NAVAIR Competency using Social Network Analysis (SNA) and to develop recommendations for improvement. It is important because NAVAIR is committed to operating efficiently and effectively as one team across its large, complex and geographically dispersed organization, providing advanced technology solutions to the warfighter.

The results of the study provided valuable insight and data to address the four research questions.

1.) How do the national sites currently share knowledge and expertise in the national competency organization?

The National Materials Competency sites currently share knowledge and expertise as shown in the SNA metrics and sociograms developed from the survey data and the InFlow 3.0 software. Generally, it can be concluded that the National Materials Competency operates with a 66% probability that collaboration is occurring integrated across all of the areas investigated. Significant network challenges exist to improve the integration of China Lake and Lakehurst more fully into the organization's flow of knowledge and expertise. Important linkages need to be established with sufficient frequency within the National Level 4 Competencies to ensure adequate socialization of knowledge and expertise. Social networks should be improved overall in the areas of science and technology and acquisition to enhance connectivity and the flow of knowledge and expertise regarding research and engineering requirements and opportunities by creating the necessary links between sites and between members of the same National Level 4 Competency. This would help reduce the average path length between the leadership and transform the network's operation to be more representative of a cluster.

Today, a great deal of the flow of knowledge and expertise is conducted via e-mail which has limited capabilities to build social capital and can often hinder its development. The National Materials Competency operates without the advantage of videoteleconferencing where virtual face-to-face communications can facilitate social capital development.

2.) To what extent does each site currently contribute, participate and collaborate in key National Materials Competency products and processes across the life cycle?

The extent that each site currently contributes, participates and collaborates in key National Materials Competency products and processes across the lifecycle has been described. The sociograms provide visualizations of both the directionality and frequency (indicated by the boldness of the line) of knowledge flow within and between individuals and sites for the key products and processes. A large portion of the flows observed were one-way flows which indicates that additional opportunities for combination and exchange of knowledge and expertise exist. Two-way flows of knowledge and expertise within the National Level 4 Competencies in general, and between China Lake, Lakehurst and North Island need to be substantially improved. Isolates exist within the National Level 4 Competencies for Nondestructive Inspection and Corrosion/Wear. These leader are not actively engaged and participating in National Materials Competency Level 4 products and processes.

3.) What patterns of relationships exist among National Materials Competency Leadership and Senior Technical Specialists?

The patterns of relationships are represented by the baseline structural visualizations and the emergent structures in the arranged sociograms. A near-star topology exists at the site level with few two-way connections linking North Island, China Lake or Lakehurst. China Lake's and North Island's single site level 3 leader are the principle interfaces from those organizations with the rest of the National Competency. A relatively strong cluster exists in symmetric ties between Patuxent River, Cherry Point and Jacksonville indicative of relatively higher social capital and higher exchange of knowledge and expertise. These patterns should exist between all of the National Materials Competency sites. Strong two-way flows exist within each individual site are evident where close face-to-face interactions lead to increased social capital and the strong flow of local knowledge and expertise. Overall, observed patterns follow a number of forms including strong clusters within each site, and variations of star topologies between critical sites, star topologies within the National Level 4 Competencies indicating leader dominance but minimal team cohesion, and isolates within National Level 4 Competencies that are not participating in the National Level 4 activities that they are assigned.

4.) How can the efficacy of the NAVAIR Materials Division National Materials Competency be improved by enhancing the flows of knowledge and expertise?

This thesis has shown that the efficacy of the NAVAIR Materials Division National Materials Competency can be improved by enhancing the flow of knowledge and expertise across the National Level 3 Competency leadership, across the Materials Competency's geographically dispersed sites, as well as within the National Level 4 Competencies. Improvements can be made to better integrate China Lake, North Island and Lakehurst more directly into the existing organizational networks, especially between National Level 4 members. This would build intellectual capital across the National Materials Competency by better leveraging cohesion within the organization and brokerage external to the organization. The efficacy of the National Materials Competency would be improved across all competency products and processes. By enhancing the flow of knowledge and expertise, the National Materials Competency could foster the concept of the national level 4 leadership organization to help improve the quality of research and engineering products and services such as: improved science and technology innovation and transition; improved materials selection and development, engineering criteria and standards, test and evaluation, corrosion prevention, and environmental compliance for acquisition programs; improved understanding of in-service engineering requirements and opportunities; increased business base and reduced competition for resources; more consistent national-level management and administration of Materials Competency operations; and improved national strategic planning activities which better synergize national resources and assets to reduce duplication, improve utilization, and better leverage strategic opportunities. Improved flow of knowledge and expertise would increase social capital, overall National Materials Competency cohesion, and lead to more substantial exchange and combination of knowledge and expertise to facilitate intellectual capital & innovation.

B. IMPLICATIONS

The implication of this thesis is that SNA provides a useful tool for assessing the flow of knowledge and expertise across a geographically dispersed organization. It introduces a meaningful concept and operational model for high performance organizational self-assessment, evaluation, and proactive action to improve operations. The sociogram visualizations are effective in identifying areas for management attention and focus. SNA offers a conceptual framework to help drive organizational networks toward optimum performance by highlighting those areas where inter-connectivity does and does not occur. The SNA process and computer-based tools allow for an efficient and effective organizational application across myriad groupings, processes, and products. SNA provided strong indications of areas for improvement that otherwise would not have been quantified or easily acknowledged and offers the potential for facilitating the synergy of any local or geographically dispersed activities. Also, SNA can be expanded to include larger scale activities, and organizations as a whole to drive optimum performance.

C. SNA LIMITATIONS

SNA provides a valuable tool that can help to better understand organizational flows, organizational opportunities and challenges, provide leadership the insights it needs for action, and has an ability to persuade and influence network improvements through the visualization of community generated data and visualizations. Some of the key limitations of the thesis SNA include:

- There are no standards from which SNA networks can be compared making it difficult to assess whether a change in network structure is an advantage or disadvantage

- Despite the fact that the thesis survey questions were posed in terms of knowledge flow, knowledge flow is a difficult concept for organizations to understand. The SNA diagrams and analyses developed in this thesis may reflect the combined communications of data, information and knowledge. The interpretation of the thesis results should be considered as such.

- The qualitative judgment by the respondents regarding how frequently knowledge flows (based on recollection vice hard historical data logs) could affect data quality and variance. The interpretation of the thesis results should be considered as such.

- The study does not consider the complex allocation of organizational time and resources. Increasing the knowledge/communication flow between any two nodes/people/organizations may adversely hurt performance.

- All survey respondents were identified by name and work for the author who is the National Level 3 Materials Competency Leader. This situation introduces some limitations into the objectivity of the respondents' survey data.

- The specificity/generality of the questions relate directly to the results and the context of those results. Each survey question is a broad subject area covering a large domain of potential knowledge flow. Therefore, the interpretation of the thesis results must be viewed at this level.

- The myriad flow mechanisms (face-to-face, e-mail, phone etc.) and their relationship to actual knowledge exchange/combination is difficult to quantify or characterize. This thesis considered knowledge flow summarized from all mechanisms based on the opinions of the respondents. Face-to-face knowledge flow is felt to build the strongest social capital and facilitates knowledge flow.

This is a contributing factor to strong local site cohesion and a constraint affecting external brokerage across the sites.

- SNA metrics and visualizations can be difficult to integrate into overall assessments of organizational network connectivity. The integration of network metrics with visualization and open-ended responses facilitates an understanding of network characteristics and impediments, however, the synthesis and derivation of management solutions is often difficult to distill and relate to organizational performance.

D. RECOMMENDATIONS

Based on this thesis, SNA is a valuable tool for understanding the true operations of an organization. It is able to analyze organizational network performance and interconnectivity at the individual, group, or activity level. Clearly, the Naval Air Systems Command strives for organizational alignment leveraging synergy across and within sites, teams, and Competencies. SNA provides an ability to address and drive organizational change related to social network issues that can hamper and impede performance. Coupled with directed survey open-ended responses, an understanding of the interaction of organizational network performance with social, cultural, political, and technical challenges can be developed, and management-driven improvements can be identified, measured and compared to a baseline. SNA provides an ability to apply network analysis and management concepts to the organizational leadership and management environment.

As a result of this thesis, the National Materials Competency has a number of recommendations for consideration:

- The MMB must formulate action plans to address those areas identified in the Part II Survey that impede the flow of knowledge and expertise, and evaluate those recommendations developed as part of a collective set of management initiatives to improve organizational connectivity and effectiveness.

- Management-driven communications and cross-site work products will greatly facilitate the development of social capital and enhance the flow of knowledge and expertise within the National Materials Competency.
- The fostering of the National Level 4 organizational concept will help improve social capital, lead to more substantial flow and combining of knowledge and expertise, and greatly facilitate innovation.
- The development and establishment of a core training curriculum for the National Materials Competency would help codify tacit knowledge, and in its explicit form will be more available for pervasive application.
- Increased rotational assignments will help build trust and mutual respect, the underpinnings of an effectively networked organization.
- The development of a competency web site and directory will enhance awareness of expertise and capabilities and enable effective working links to be established.
- The introduction of the Aerospace Materials Technology Consortium will provide a tele-collaborative forum for exchange of data, information and knowledge throughout the aerospace materials community, including linkages to data repositories and information sources as well as providing an infrastructure for synchronous and asynchronous communications via video, voice and text mark-up.

E. FUTURE RESEARCH

Conceptually, SNA can provide useful insights regarding organizational communications and networks, knowledge management, social capital, intellectual capital, and organizational learning and innovation. New web-based tools are now available at www.Knetmap.com which leverage the InFlow 3.0 tool to provide a service which solicits organizational responses to questions through a defined period of time and automatically generates SNA visualizations and metrics based on the responses. This extension of SNA provides for automated data and sociogram generation, the enable an organization to identify network performance characteristics and help focus management attention on those areas with greatest leverage. This concept should be evaluated for future application to the National Materials Competency and the Naval Air Systems Command organizational environment.

SNA can be used to study the relationship between organizational networks and SNA metrics. Further study is required to correlate organizational performance and SNA metrics. In addition, organization's can develop models of networks for their unique organizations and determine the virtual metrics indicative of what management believes would represent an optimum functioning organization. These metrics and visualizations can be used for comparison with existing organization SNA data.

Based on the results of this thesis, the National Materials Competency Materials Management Board is now identifying future analyses to be conducted using SNA methodologies and tools. Prototypes are being planned to address local overall site connectivity, as well as overall National Level 4 connectivity. Once prototypes are conducted, the results will be analyzed and follow-on analyses performed. Further extension of SNA to larger sample sizes, customers, and external partners including industry, academia and other government agencies offer the potential to more fully characterize social network relations and the flow of knowledge and expertise.

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Appendix A

NAVAIR

THE CREDO • PRINCIPLES OF ALIGNMENT

WE AIM TO REPRESENT THE HIGHEST STANDARD IN WARFARE TECHNOLOGY THROUGH SUPREMACY IN NAVAL AVIATION TECHNOLOGIES.

OUR MISSION IS TO ENABLE ABSOLUTE COMBAT POWER THROUGH TECHNOLOGIES THAT DELIVER DOMINANT COMBAT EFFECTS AND MATCHLESS CAPABILITIES.

OUR ROLE IS TO BE THE ULTIMATE TECHNOLOGY PROVIDER, AUTHORITY AND ACTION RESOURCES FOR NAVAL AVIATION TECHNOLOGIES FOR THE WARFIGHTER.

OUR DUTY IS TO MAINTAIN UNSURPASSED KNOWLEDGE, EXPERTISE AND EXPERIENCE IN NAVAL AVIATION TECHNOLOGIES AND THE HIGHLY SPECIALIZED FACILITIES ESSENTIAL TO ENGAGE AND DEVELOP THEM; AND TO RESPOND URGENTLY, ACCURATELY AND EFFECTIVELY TO THE CALLS OF OUR WARFIGHTER.

WE EXERCISE PLATINUM STANDARDS ACROSS OUR ORGANIZATION TO INSURE OPERATIONAL INTEGRITY AND ABSOLUTE SAFETY IN ALL NAVAL AVIATION ASSETS.

WE STRIVE TO KEEP OUR PRODUCTS WARFIGHTER-FRIENDLY! EASY, EXACT AND TIMELY.

WE PLEDGE TO REMAIN INTIMATE WITH THE WARFIGHTER AND THE EVOLVING BATTLESPACES IN WHICH THEY ENGAGE.

WE ACT AS A SEAMLESS NETWORK OF DIVERSE ELEMENTS BOUND BY A COMMON VISION, PURPOSE AND COLLECTIVE DESTINY; AND NEVER ALLOW ANY PAROCHIAL INTERESTS TO VIOLATE THE SANCTITY OF THE COLLECTIVE NAVAIR.

WE FORM VIRTUAL UNIONS WITH OUR FELLOW SYSTEMS COMMANDS AND OTHER PROVIDERS TO ENSURE OPTIMUM SOLUTIONS FOR OUR NETWORKED FIGHTING FORCES.

WE PARTNER WITH THE BEST OF INDUSTRY TO AUGMENT OUR CAPABILITIES, INCREASE OUR KNOWLEDGE, EXPERTISE AND EXPERIENCE AND TO MORE EFFICIENTLY COMPLETE OUR WORK.

WE MAXIMIZE TAXPAYER VALUE BY DEVELOPING EVER GREATER WARPOWER WITH INCREASINGLY EFFICIENT TECHNOLOGIES.

WE PASSIONATELY PURSUE INCREASING THE SPEED, STEALTH, POWER, PRECISION, AGILITY AND INTELLIGENCE OF OUR WARFIGHTING TO ENABLE SUCCESS IN THE BATTLESPACE.

REIGN SUPREME - RETURN IN GLORY
IS THE ULTIMATE PROMISE WE MAKE TO THE WARFIGHTER.

NAVAL AVIATION TECHNOLOGIES

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Appendix B

MATERIALS COMPETENCY ORGANIZATIONAL DEFINITIONS

4.3.4 MATERIALS

The Materials Competency is responsible for the people, processes, policies and facilities to provide full spectrum materials science and engineering principles to the full lifecycle research, development, acquisition and in-service engineering, selection, qualification and safety-of-flight certification of advanced materials, manufacturing and maintenance processes for all Naval Aviation products including acquisition programs and in-service support. The Materials Competency ensures Naval Aviation Systems incorporate the best combination of materials and processes research, development and engineering principles and practices. The work of the competency requires a close interaction with other Competencies, Integrated Product Teams (IPT) and enterprise missions. The Materials Competency provides direction and guidance to other Level I, II and III Competencies including Air Vehicle Structures, Air Vehicle Subsystems, Propulsion and Power, Avionics & Sensors, Crew Systems, Aircraft Launch and Recovery Equipment, Support Equipment and Weapons as well as the Logistics and Industrial Competencies. The Materials Competency conducts a broad and extensive Research and Technology program fully leveraging the expertise and capabilities of other Navy labs, DOD, industry, universities, and other agencies to ensure superior products and services.

The Materials Competency includes metals/ceramics, industrial/operational chemicals, nondestructive inspection, polymers/composites, analytical test and analysis, and corrosion/wear. Critical path networking, trades studies, lessons learned, and quantitative risk analysis tools are employed to establish relationships between the materials evaluation process and other critical program objectives of cost, weight, schedule, environmental compliance and performance. Materials are selected for low risk transition to appropriate platforms based on, as a minimum, application compatibility, statistically significant allowables testing, maturity of manufacturing and processing technology, manufacturing process control and verification, and in service repairability. Where necessary, the Materials Competency will institute enterprise and manufacturing technology programs utilizing government and contractor laboratories, and the National Centers and implement the results of the efforts as appropriate to support Team products. The Materials Competency serves as the Command’s lead for the Aircraft Corrosion Control and Prevention Program (AC^2P^2), and acts as the AIR-4.0 Research and Engineering Group’s representative and coordinator for Environmental Compliance and Pollution Prevention initiatives including the AIR-8.0 led Command Acquisition Environmental Product Support Team (AEPST).

4.3.4.1 METALS/CERAMICS

The Metals/Ceramics Competency involves the conception, development, and application of metallurgical and ceramic science and engineering including metal matrix composites. The Metals/Ceramics Competency is responsible for establishing policies and procedures governing the selection, manufacturing and repair processes, qualification and use of metallic and ceramic materials as well as defining and adopting standardized performance based requirements for metallic and ceramic materials and processes. The Metals/Ceramics Competency is responsible for guiding the development and characterization of metals and ceramics and their processes. The competency provides metallurgical materials evaluation and consultation in support of weapon system maintenance by developing metallic repairs, coordinating engineering investigations, and exercising technical control over metallurgical processes. The Metals/Ceramics Competency is responsible for coordinating and evaluating data, developing specifications, standards, and requirements, developing selection criteria, ensuring environmental compliance, executing Metals/Ceramics engineering and failure investigations, and authorizing the final selection and application of metals and ceramics and their processes for acquisition and in service support.

4.3.4.2 INDUSTRIAL/OPERATIONAL CHEMICALS

The Industrial/Operational Chemicals Competency involves the conception, development, and application of industrial and operational chemical science and engineering. The Industrial/Operational Chemicals Competency is responsible for establishing policies and procedures governing industrial and operational chemical selection, qualification and utilization as well as defining and adopting standardized performance based requirements for industrial and operational chemical materials and processes. The competency is responsible for guiding the development and characterization of industrial and operational chemicals and their processes. Such industrial and operational chemicals are either organic or inorganic and they include cleaners, strippers, electroplating solutions, paints/primers, surface preparation solutions, hydraulic fluids, greases, and de-icing fluids. The work of the competency includes in process verification, troubleshooting, and process improvement for industrial and operational chemicals critical to the production and maintenance operations including depainting and cleaning operations, surface treatment. The competency is responsible for coordinating and evaluating data, development specifications, standards and requirements, ensuring environmental compliance, developing selection criteria and authorizing the final selection and application of industrial and operational chemicals and their related processes for acquisition and ISS.

4.3.4.3 NONDESTRUCTIVE INSPECTION (NDI)

The NDI Competency involves the conception, development, and application of NDI principles and techniques. The NDI Competency is responsible for establishing policies and procedures governing NDI development, selection, qualification, and utilization as well as defining and adopting standardized performance based requirements for NDI. This includes correlating effects of defects with NDI, establishing requirements for the use of nondestructive testing (NDT) results as a tool for statistical process control, NDT of component and full scale test articles, and materials review board NDT records retention and traceability. The NDI Competency is responsible for evaluating proposed NDI acceptance criteria and reference standards. The NDI Competency is responsible for ensuring the format of contractor inspection data is compatible with that of the fleet support team activities. The NDI Competency is responsible for coordinating and evaluating data, developing specifications, standards, and requirements, as well as developing technique and equipment selection criteria. The NDI Competency is responsible for nondestructive verification of the serviceability of Team products by developing, certifying, and employing inspection procedures during acquisition and ISS.

4.3.4.4 POLYMERS/COMPOSITES

The Polymers/Composites Competency involves the conception, development, and application of polymers/composites science and engineering principles. The Polymers/ Composites Competency is responsible for establishing policies and procedures governing polymers/composites selection, manufacturing and repair processes, qualification and utilization, as well as defining and adopting standardized performance based requirements for polymer/composite materials and processes. The Polymers/ Composites Competency is responsible for guiding the development and characterization of polymers, polymer matrix reinforced composites (e.g., graphite, fiberglass, Kevlar fibers), electromagnetic and signature materials and their processes. Such polymeric items are either elastomeric in nature (e.g., fuel cells, life rafts, o-rings, hoses, seals), plastic in nature (e.g., windows, canopies, instrument panels) or composites reinforced with continuous or discontinuous reinforcements. This level 4 competency also includes structural plastics as well as sealants, organic coatings, and adhesives. The Polymers/Composites Competency is responsible for coordinating and evaluating data, developing specifications, standards, and requirements, developing selection criteria, ensuring environmental compliance, executing polymer/composites engineering and failure investigations, and authorizing the final selection and application for polymers/composites and their processes for acquisition and in-service support.

4.3.4.5 ANALYTICAL CHEMISTRY & TESTING

The Analytical Chemistry and Testing Competency involves the conception, development, and application of analytical testing and analysis. The competency is responsible for establishing policies and procedures governing analytical chemistry test and analysis selection, qualification and use as well as defining and adopting standardized requirements and guiding the development for analytical test and analysis procedures. The competency is responsible for coordinating and evaluating data; developing specifications, standards, and requirements; developing test and analysis procedure selection criteria; in-process control for fleet and industrial operations; and authorizing the final selection of analytical test and analysis procedures for acquisition and ISS. Analytical testing and analysis is performed on metallic and non-metallic materials associated with aviation weapon systems (e.g., gases, metals, polymers, industrial chemicals and operational fluids, coatings, and contaminants) using various spectrometric, chromatographic, and physical property techniques. In service testing and analysis is performed in support of design changes, engineering and failure investigations, and industrial processes.

4.3.4.6 CORROSION/WEAR

The Corrosion/Wear Competency involves the conception, development, and application of corrosion/wear science and engineering. The Corrosion/Wear Competency is responsible for establishing policies and procedures governing corrosion and wear prevention and control selection, manufacturing and repair processes, qualification and utilization as well as defining and adopting standardized performance based requirements for corrosion and wear prevention and control. The competency is responsible for guiding the development of corrosion/wear prevention and control practices as well as identifying mechanisms, causes, and effects. The competency is responsible for coordinating and evaluating data, developing specifications, standards, and requirements, developing corrosion/wear prevention and control practice selection criteria, executing corrosion/wear engineering and failure investigations, and authorizing the use of corrosion/wear prevention and control practices for acquisition and in service support. Corrosion/wear prevention methods are evaluated and selected based upon material characteristics, environmental compliance, galvanic combinations, and surface treatment. Encompasses the engineering activity necessary to provide full lifecycle materials and characterization efforts. Serves other level 1 and 2 organizations, which include Propulsion, Avionics, Crew Systems, Aircraft Launch and Recovery Equipment, Support Equipment and Weapons, Logistics, and Industrial Operations. Direction and guidance are provided to ensure that systems incorporate the best combination of materials engineering principles. Provides RDT&E, engineering, analyses, application studies, and testing necessary for specifying the design, validation, and certification of materials on assigned systems.

APPENDIX C

NATIONAL LEVEL 3 MATERIALS COMPETENCY SITE AND COMPETENCY ALIGNMENT

Node #/Code(s)	Site	Position for:	Site Supervisor or Staff	Metals/Ceramics	Ind'Op Chemicals	NDE	Poly/Composites	Anal Chem	Corrosion/Wear
001/4.3.4	PAX	National Level 3	X						
002/4.3.4 Staff	PAX	Senior Staff	X						
003/4.3.4 Staff	PAX	Senior Staff	X						
004/4.3.41, .3	PAX	National Level 4		X		X			
005/4.3.42,.5,.6	PAX	National Level 4			X			X	X
006/4.3.44	PAX	National Level 4					X		
007/4.3.4	CHPT	Site Level 3	X						
008/4.3.42, .3, .6	CHPT	Site Level 4			X	X			X
009/4.3.44,5	CHPT	Site Level 4					X	X	
010/4.3.4	JAX	Site Level 3	X						
011/4.3.41, .3	JAX	Site Level 4		X		X			
012/4.3.42, .4	JAX	Site Level 4			X		X		
013/4.3.45, .6	JAX	Site Level 4						X	X
014/4.3.4	NI	Site Level 3	X						
015/4.3.41, .2, .4, .6	NI	Site Level 4		X	X		X		X
016/4.3.4	Lakehurst	Site Level 3	X						
017/4.3.41, .6	Lakehurst	Site Level 4		X					X
018/4.3.42, .4	Lakehurst	Site Level 4			X		X		
019/4.3.43, .5	Lakehurst	Site Level 4				X		X	
020/4.3.4	China Lake	Site Level 3	X						
021/4.3.41	China Lake	Site Level 4		X					
022/4.3.42	China Lake	Site Level 4			X				
023/4.3.43	China Lake	Site Level 4				X			
024/4.3.44	China Lake	Site Level 4					X		
025/4.3.45, .6	China Lake	Site Level 4						X	X

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APPENDIX D

National 4.3.4 Materials Competency Leadership Survey

Name:

Instructions:
1) Pls fill in your name above
2) Questions are provided on the right
3) Pls click on each cell and use the drop down list for answers 1 to 5 or leave blank if interactions are less than yearly or no interaction

PART 1

Persons you share knowledge with: Node/Competencies	S&T Q1	ACQ Q2	ISE Q3	Bus Dvml Q4	Mgmt Q5	Strategic Planning Q6
001/4.3.4						
002/4.3.4 Staff						
003/4.3.4 Staff						
004/4.3.4.1, .3						
005/4.3.4.2,.5,.6						
006/4.3.4.4						
007/4.3.4						
008/4.3.4.2, .3, .6						
009/4.3.4.4,.5						
010/4.3.4						
011/4.3.4.1, .3						
012/4.3.4.2, .4						
013/4.3.4.5, .6						
014/4.3.4						
015/4.3.4.1, .2, .4, .6						
016/4.3.4						
017/4.3.4.1, .6						
018/4.3.4.2, .4						
019/4.3.4.3, .5						
020/4.3.4						
021/4.3.4.1						
022/4.3.4.2						
023/4.3.4.3						
024/4.3.4.4						
025/4.3.4.5, .6						

Research Questions:
With whom and how frequently do you share your knowledge and expertise in the area of:

Q1: Science and Technology?
(6.1 Research thru 6.3 Advanced Technology Development)

Q2: Acquisition Engineering, Development and Production?
(6.4 DEM/VAL thru Production and Deployment)

Q3: In-Service Engineering?
(O&MN, Operations & Fleet Support, NADEP Production)

Q4: New Business Development?
(Marketing and Proposal Development)

Q5: Management and Administration?
(Competency, Personnel, Organizational, Facility/Equipment, Quality, Financial, Training)

Q6: Strategic Planning?
(Medium to Long Term Planning for Initiatives/Activities)

Based on Frequency of Interaction:

1 = Yearly
2 = Quarterly
3 = Monthly
4 = Weekly
5 = Daily

Leave Blank if less than yearly or no interaction

PART II | Please type your responses below

Question A)

Do you believe there are notable impediments to improving the flow of knowledge and expertise across the National Materials Competency?

If yes, what do you believe they are and what recommendations would you like to make?

Question B)

What organizational knowledge flow/exchange initiatives or capabilities do you believe would enhance the overall National Materials Competency performance, collaboration and synergy to meet short, medium and long term Competency Mission requirements as defined in the Materials Competency Charter and Competency Operating Guide?

Note: When complete please save as: "Survey Form <Name>" and return to Dale Moore at MooreDL@navair.navy.mil

Appendix E

National Level 3 Supplemental Results and Analysis

A. Level 3 Science and Technology

Figure E.1 provides the Baseline Structural Layout sociogram that shows the emphasis in science and technology at Patuxent River MD, China Lake CA and Lakehurst NJ. These three sites are part of the Naval Air Warfare Centers; the Aircraft Division and the Weapons Division. Their principal missions are principally focused on science, technology and acquisition. The Naval Aviation Depots at Cherry Point NC, Jacksonville FL, and North Island CA have principal missions focused on in-service engineering. It is clear that many observed knowledge flows are one-way, which typically does not facilitate substantial growth in intellectual capital from within the network. This is important because the exchange and combination of knowledge is necessarily to ensure in-service engineering requirements and opportunities are being addressed, as well as the strong transition of science and technology to the Naval Aviation Depots and fielded aircraft and weapon systems.

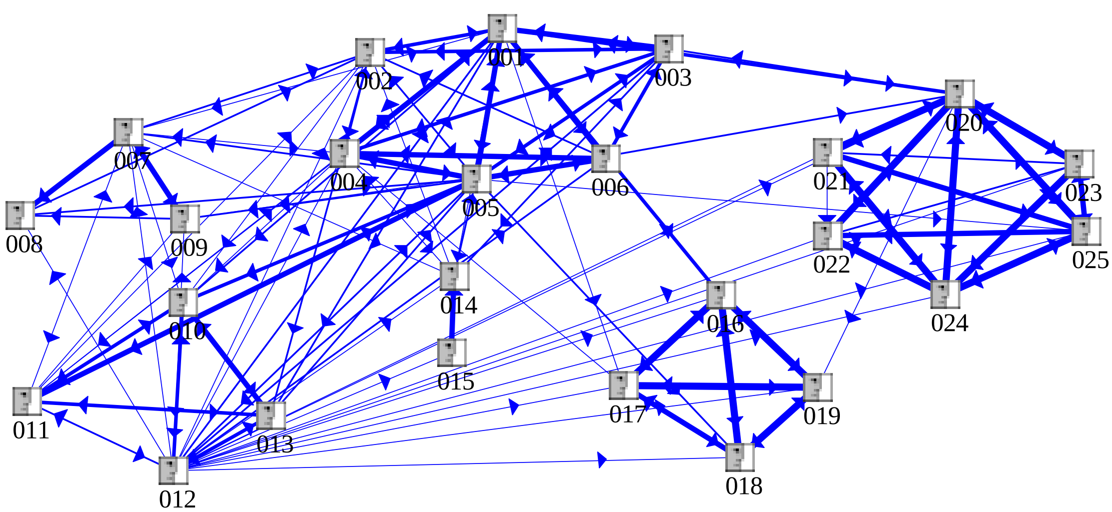

Figure E.1. National Level 3 All Responses: S&T

Figure E.2 provides the "arranged" spring embedder algorithm response for this same set of conditions, and indicates the close relationship between the NADEPs

Jacksonville FL and Cherry Point NC with science and technology community at Patuxent River MD. Lakehurst NJ and China Lake CA exhibit a strong local site knowledge flow vice across the National Level 3 Materials Competency organization.

Figure E.3 provides the national level 3 science and technology responses for frequencies 3-5 which more clearly shows the strongest relationships within the science and technology network. This depiction highlights the especially strong internal interactions within all sites but generally weak connectivity between sites. It also highlights which groups are most involved in science and technology. To improve intellectual capital across the National Level 3 Materials Competency in science and technology, more frequent flows of knowledge and expertise appear necessary. These interactions would promote increased technology development and transition to the warfighter, which offers the potential for improved system affordability and readiness.

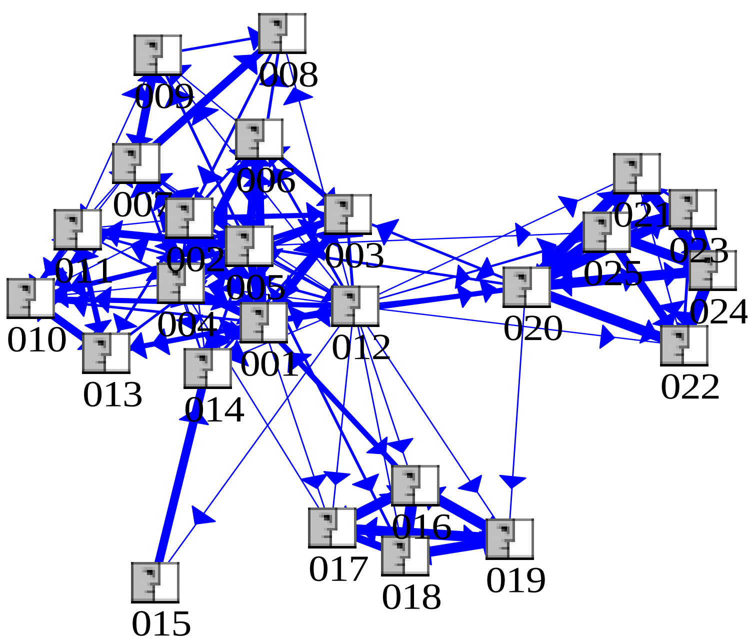

Figure E.2 National Level 3 Science and Technology: All Responses “Arranged” Emergent Structure

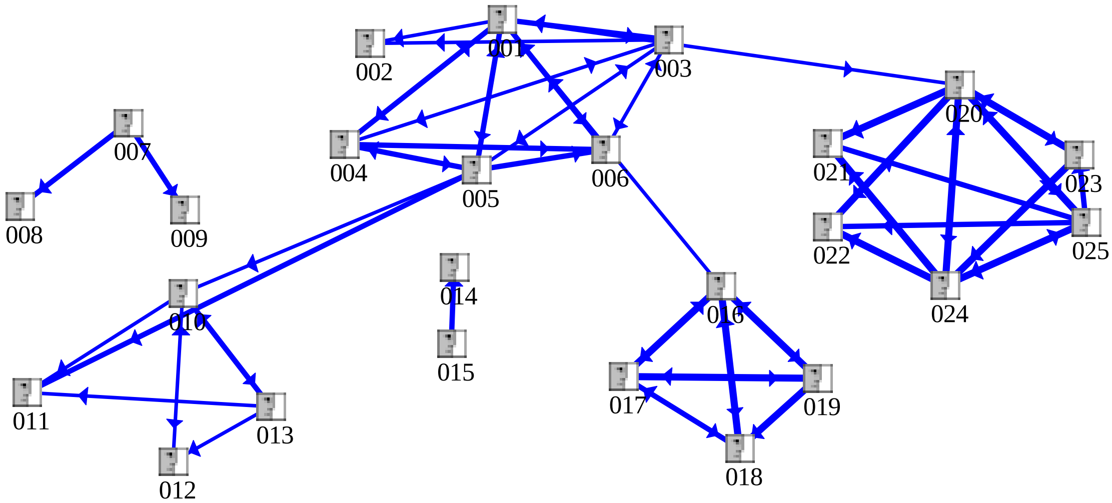

Figure E.3 National Level 3, Responses 3 –5: S&T

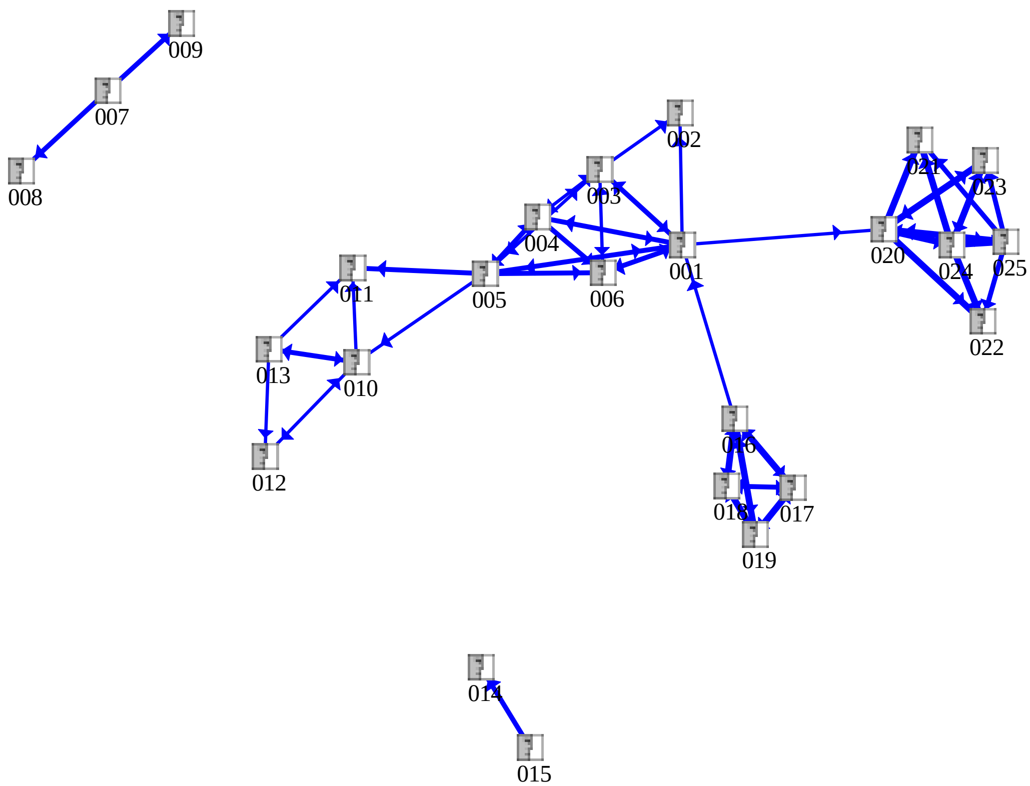

Figure E.4. National Level 3, Response 3 –5: S&T “Arranged” Emergent Structure

Figure E.4 shows the emergent structure and the relatively strong cliques that are in place at all sites. Also, Figure E.4 displays the low number of actual ties at the monthly, weekly and daily frequencies indicative of poor knowledge flow across sites. This is also evidenced by the high dispersion of nodes. Note that the sites Cherry Point NC and North Island CA have very low interactions with the other groups in science and technology, and China Lake CA and Lakehurst NJ only have single one-way links within response level 3-5 to Patuxent River MD.

B. Level 3 Acquisition

Figure E.5 shows the National Level 3 All Response for Acquisition, which emphasizes the higher involvement of the warfare centers in the acquisition development process as shown by the bold lines, and a moderate level of interaction between sites as shown by the thinner lines. Many flows appear as one-way, particularly between the sites, which limits the combination and exchange of acquisition knowledge for increased intellectual capital. Applying critical in-service lessons learned to the design and development of new acquisition systems is critical for total life cycle costs and readiness, and represents an opportunity for further organizational improvement.

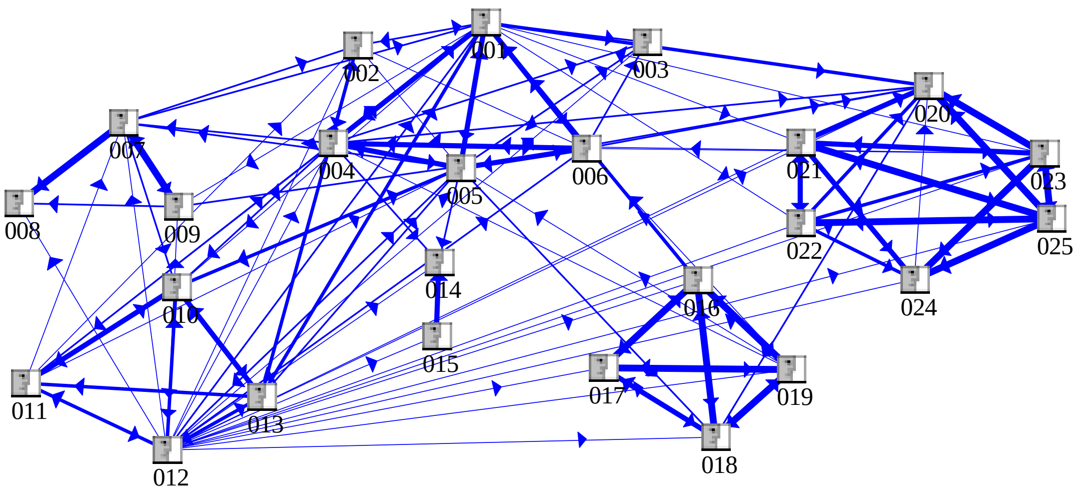

Figure E.5. National Level 3 All Response: Acquisition

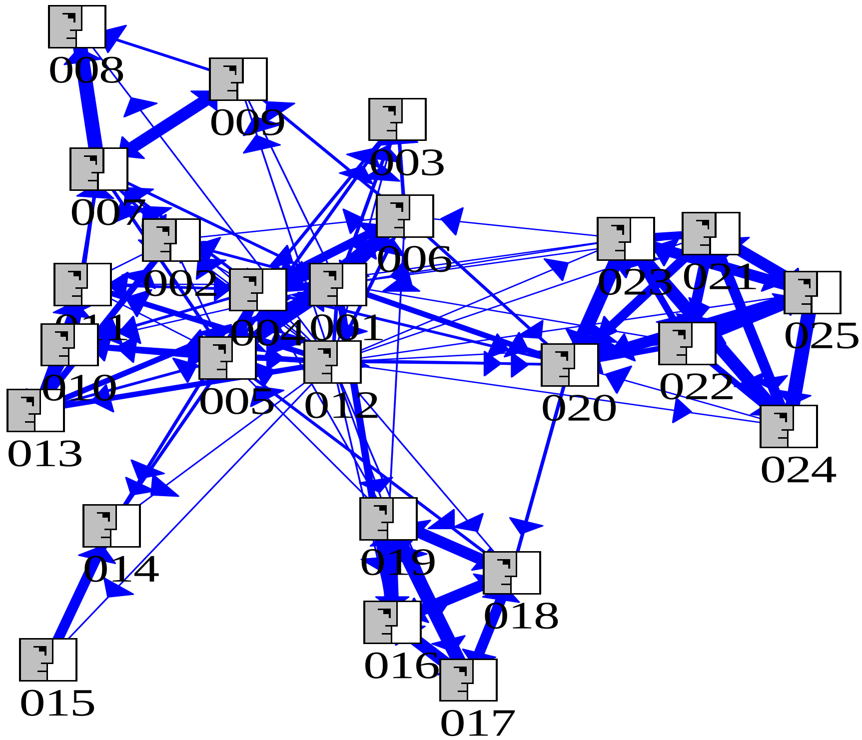

Figure E.6. National Level 3 All Responses Arranged: Acquisition

Figure E.6 reinforces Figure E.5 observations and emphasizes the weak, infrequent linkages between Patuxent River MD and China Lake CA, and Patuxent River MD and Lakehurst NJ, and Patuxent River MD and North Island CA with closer ties between Patuxent River MD and Cherry Point NC as well as Jacksonville FL. Also, strong linkages within each site are evident. Generally, a star topology is evident with Patuxent River personnel at the hub with spokes to the other sites. This is expected since Patuxent River is highly focused on aircraft acquisition within their business base.

Figure E.7 shows the strongest linkages in acquisition across the National Materials Competency. Patuxent River MD, China Lake CA, and Lakehurst NJ are all principally responsible for aircraft, weapons, aircraft launch and recovery equipment, and support equipment acquisition respectively which is shown by the frequent internal site knowledge flows. Clusters are clearly apparent within each site, and weak links are generally evident between sites. Also, the directionality of flows is important to consider mutual exchange of knowledge and expertise. Figure E.8 shows the “arranged” sociogram that emphasizes the weakness of interactions between various sites. This represents a fragile network of nodes of high dependence such as nodes 001, 010, 013, 016, and 020. Under this scenario six nodes are isolated from the network's primary cluster; 003, 007, 008, 009, 014 and 015 indicating a lack of knowledge flows from or to these nodes at the monthly, weekly and daily levels for acquisition.

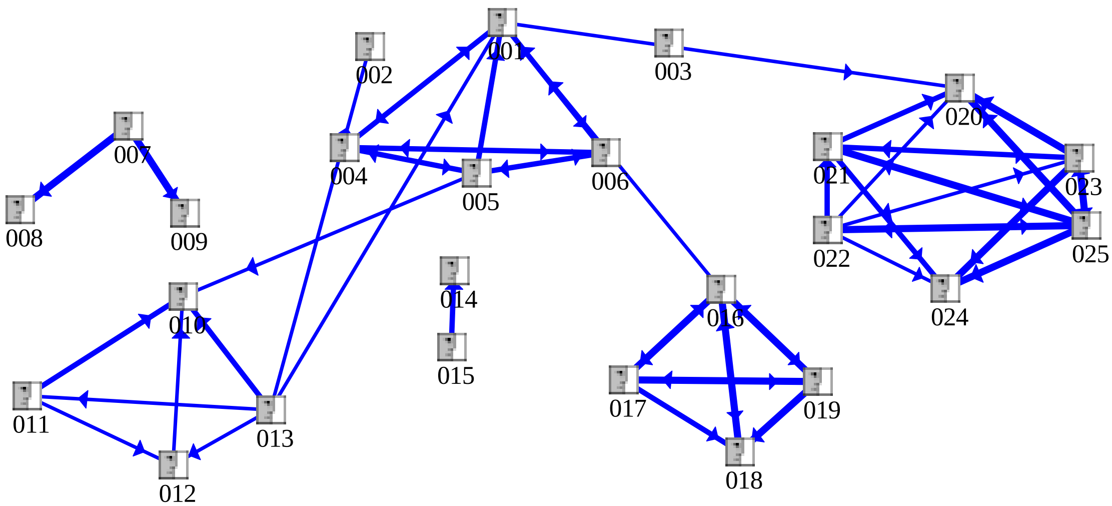

Figure E.7. National Level 3 Responses 3-5: Acquisition

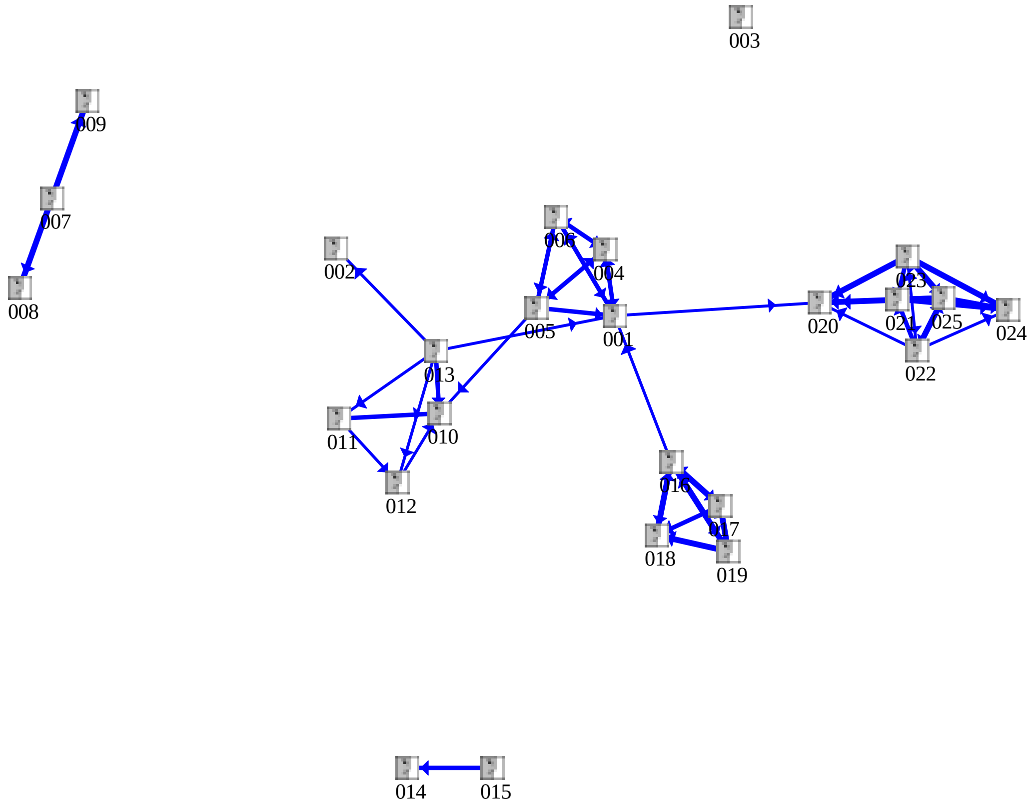

Figure E.8. National Level 3 Responses 3-5: Arranged – Acquisition

C. Level 3 In-Service Engineering

Figure E.9 shows the overall national level 3 response for in-service engineering. The greatest interactions across the national competency leadership within the product functional areas exist within the in-service engineering discipline. In-service engineering has the highest number of actual ties, the highest network density, and is tied for the highest cluster coefficient with management and administration. These interactions are often in direct response to critical fleet support demands for failure analysis and engineering investigations to support an aging equipment inventory, and typically take priority as they emerge as tactical operational issues of significant fleet impact. Figure E.10 confirms the strength of these cross-site interactions by presenting a highly centralized diagram.

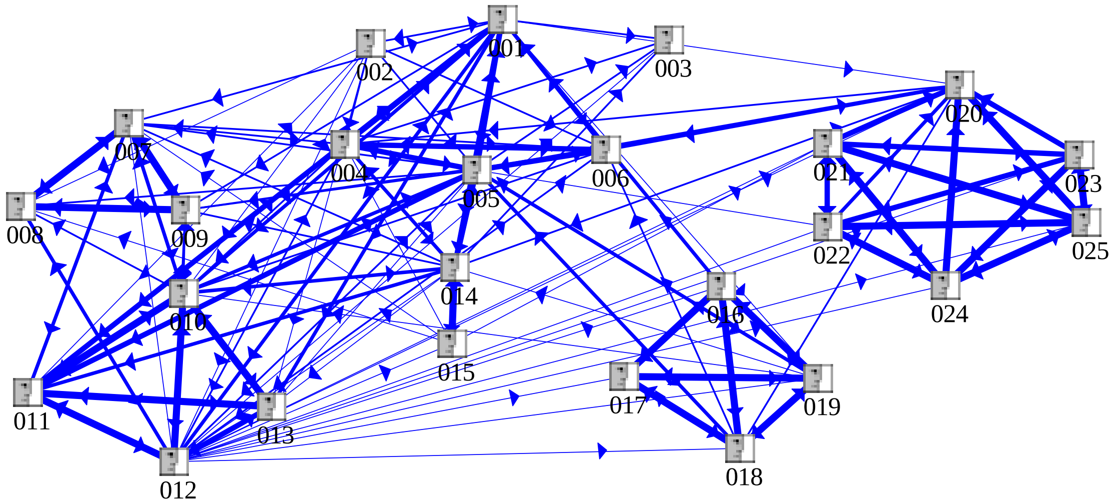

Figure E.9. National Level 3 All Responses: In-Service Engineering

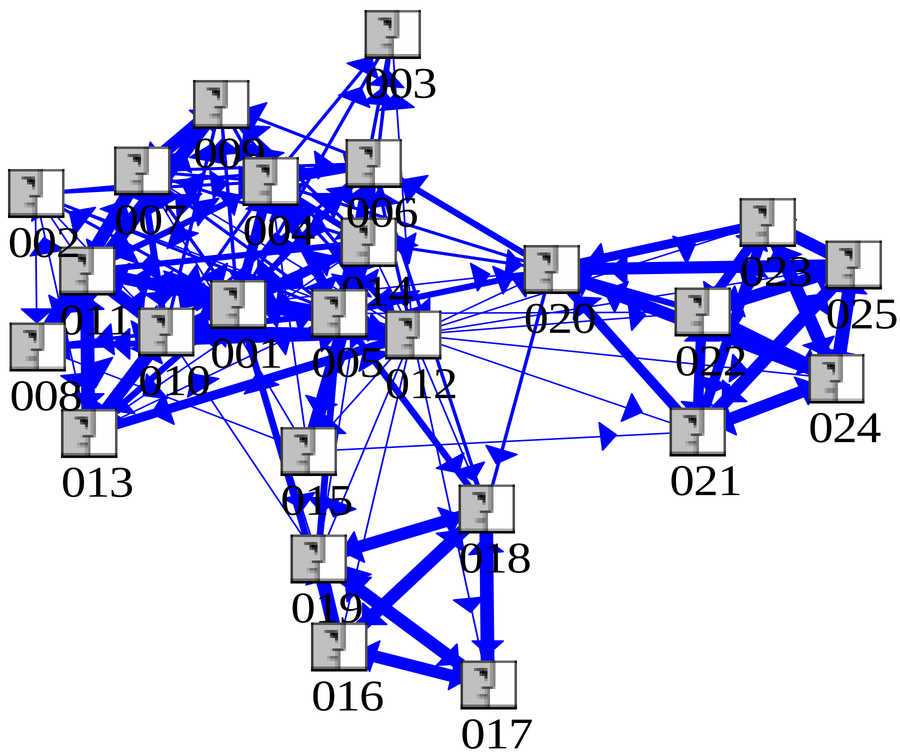

Figure E.10 National Level 3 All Responses: In-Service Engineering “Arranged”

Figure E.11 shows that many of these interactions, although they exist, are not strong and frequent. The diagrams in both Figure E.11 and Figure E.12 highlight the weak interactions and the emphasis on strong interactions at the local site level indicative of a high level of clustering for in-service engineering. Generally, local sites are directly responsible for the in-service engineering of their applications. Local sites are the resident experts regarding the subjects of local in-service engineering activities. It is anticipated that higher local site interactions regarding in-service engineering exist as compared to cross-site knowledge flows. Cross-site knowledge flows exist when highly complex in-service engineering challenges require a high degree of collaboration to ensure integrity of the engineering product such as failure analysis. Nodes 002 and 003 in Figure E.12 have a principal focus in science and technology and therefore have shown infrequent knowledge flows regarding in-service engineering. On the contrary, these nodes should become more interactive with the in-service engineering community to better understand both in-service engineering requirements, but also the opportunities to apply science and technology.

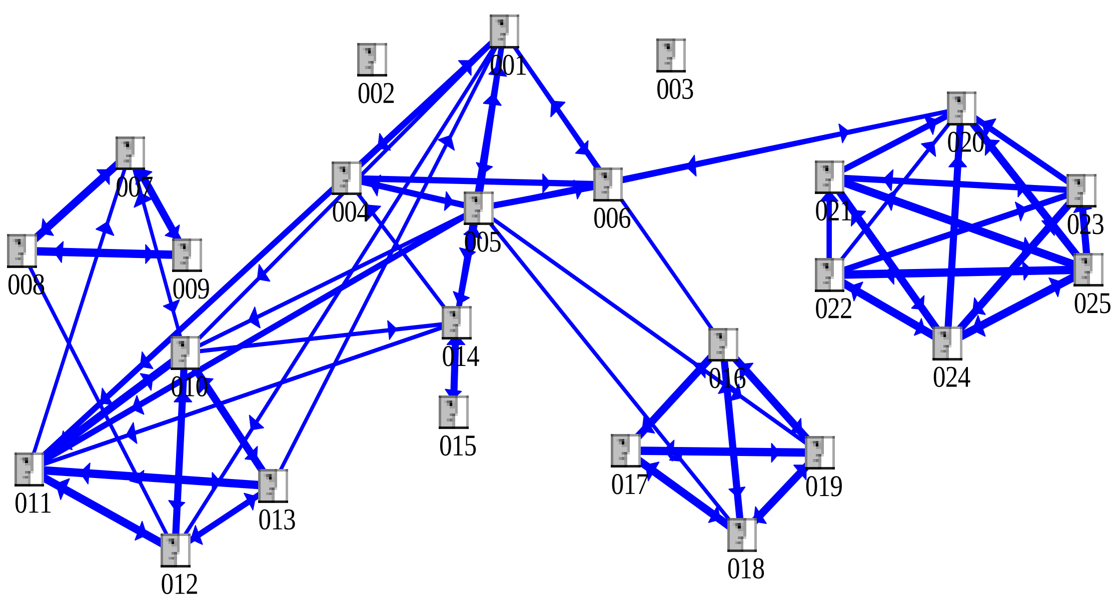

Figure E.11 National Level 3 Response 3-5: In-Service Engineering

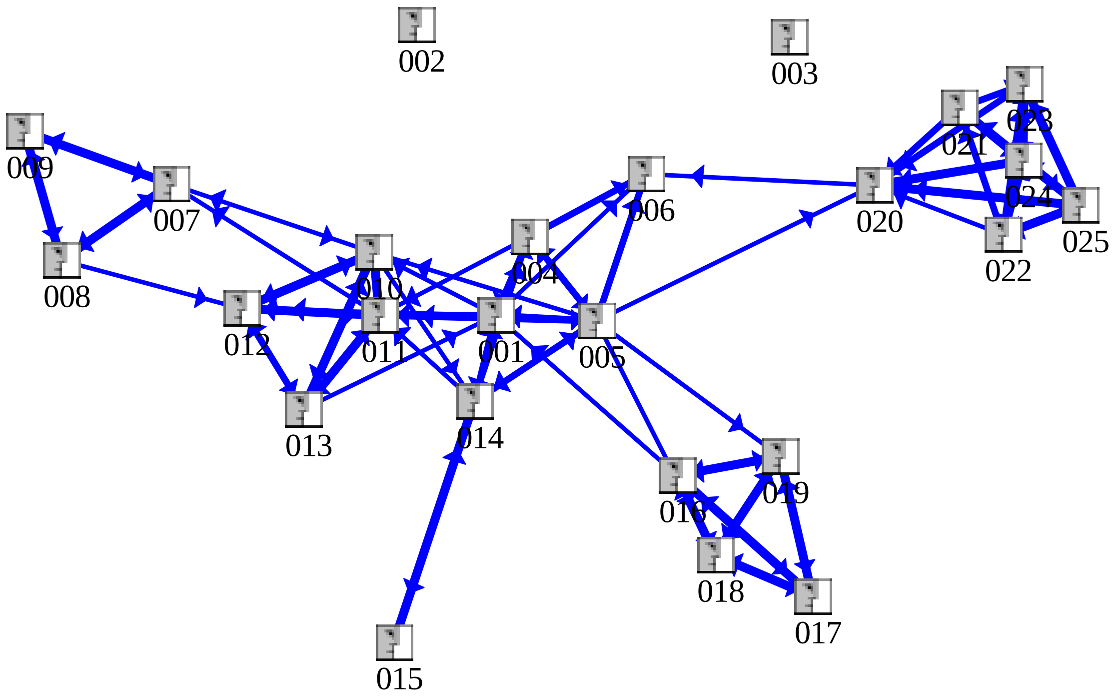

Figure E.12   National Level 3 Response 3-5: In-Service Engineering "Arranged"

D. Level 3 Business Development

Figures E.13, E.14, E.15, E.16 show that overall flow of knowledge and expertise in the area of business development is not as great as in the product development related networks based on line thickness and the number of actual ties. There exists a relatively low density of linkages and infrequent interactions between the sites in this important area. Figure E.16 also depicts a site related star topology with Patuxent River at the hub and low cross connectivity between sites. The high dispersion in Figure E.16 in the arranged form shows how fragile this network is, and how generally infrequent the interactions are across the sites. This could be due to the local emphasis on business development as a result of local financial systems and performance metrics vice national financial performance metrics. Developing a National Materials Competency business emphasis would help to foster knowledge flow across sites and develop multi-site business opportunities that leverage the capabilities and expertise across the sites.

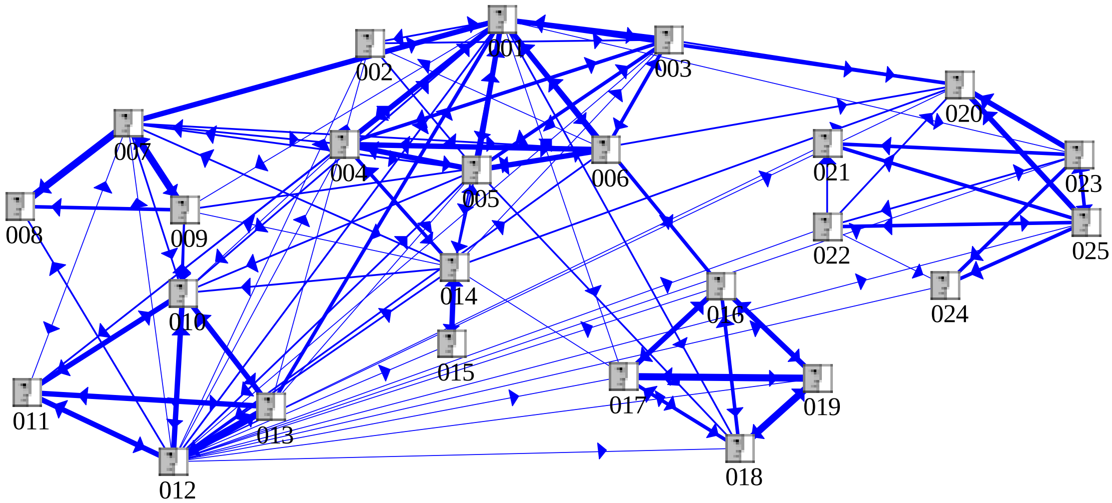

Figure E.13 National Level 3 All Responses: Business Development

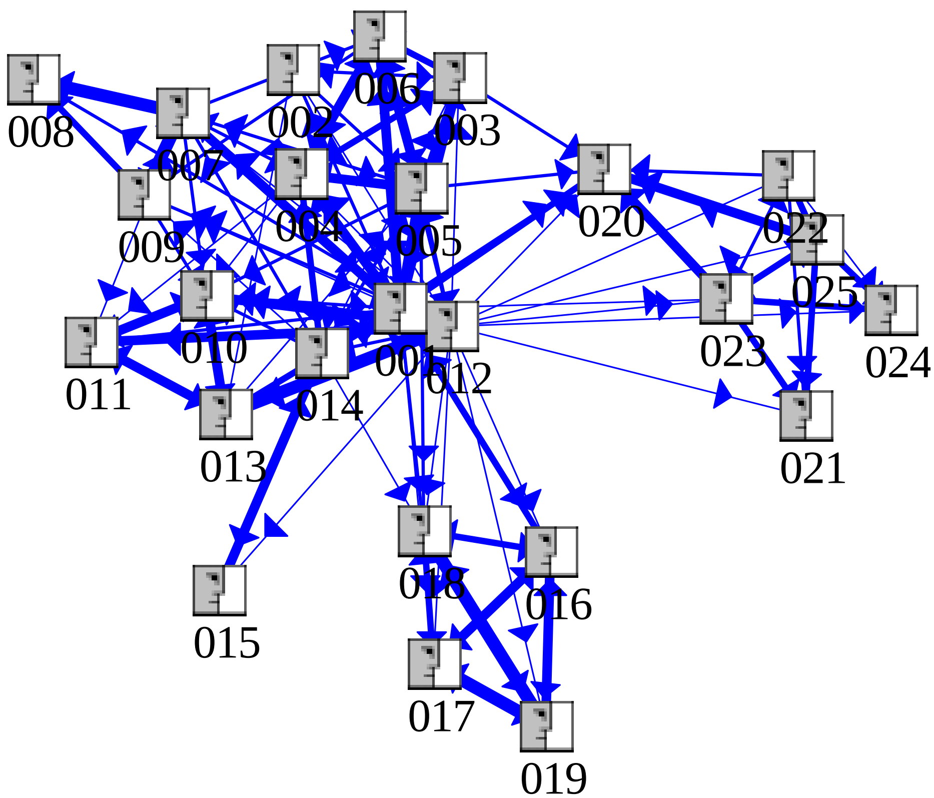

Figure E.14 National Level 3 All Responses: Business Development “Arranged”

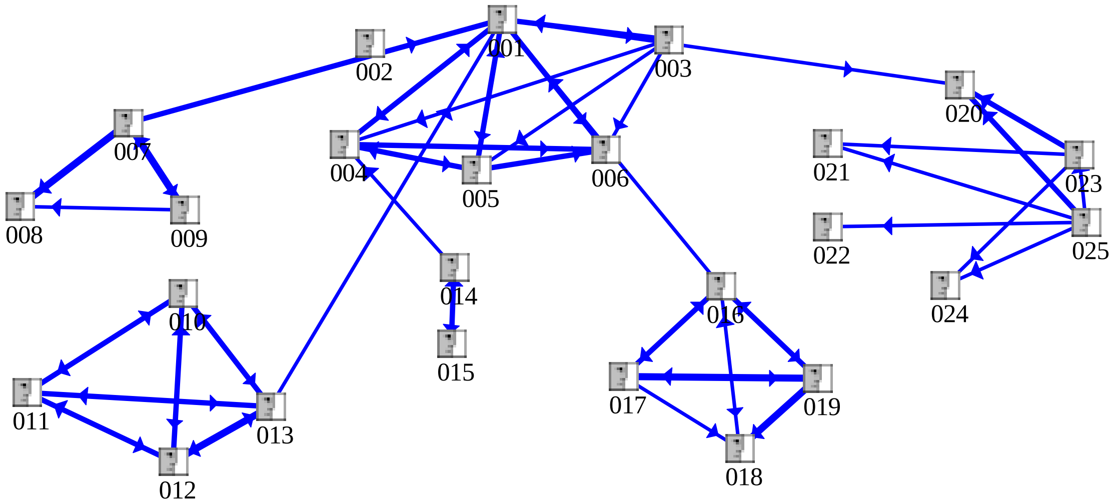

Figure E.15 National Level 3 Responses 3-5: Business Development

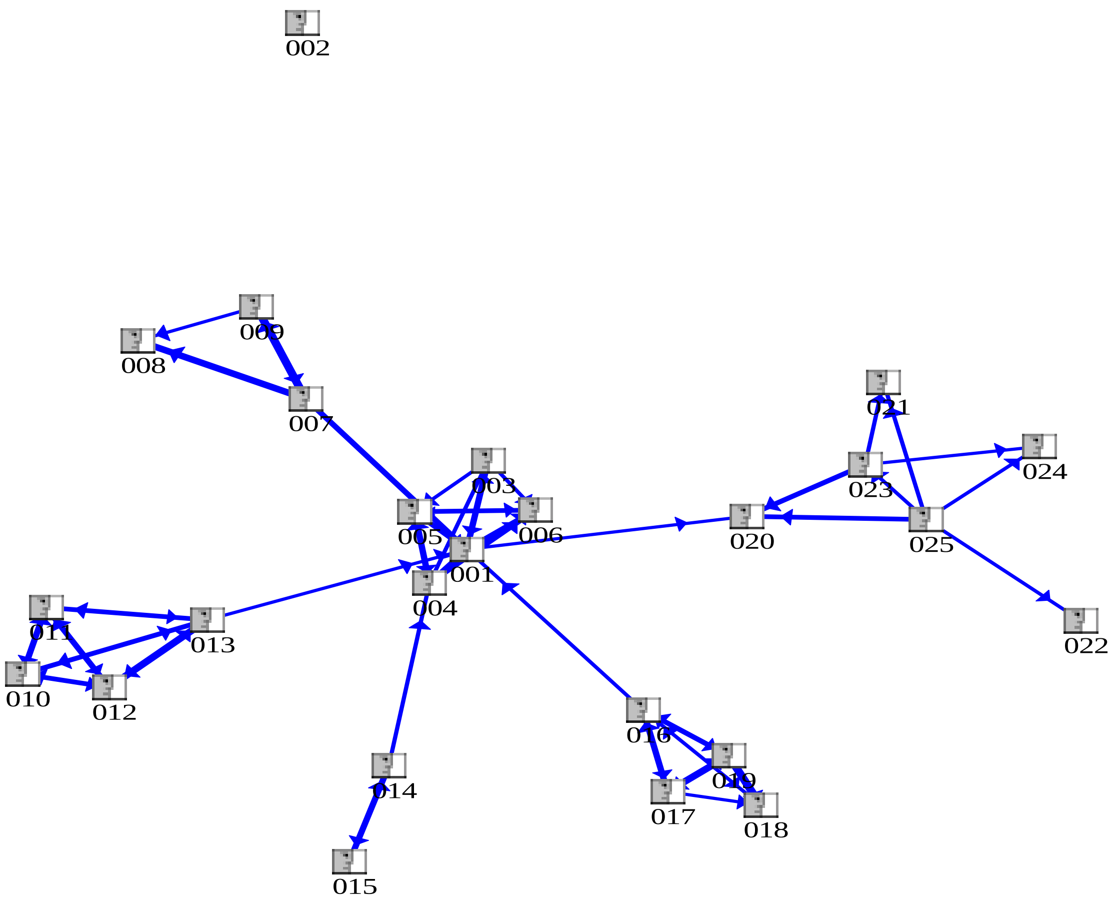

Figure E.16 National Level 3 Responses 3-5: Business Development “Arranged”

E. Level 3 Management and Administration

Figures E.17, E.18. E.19, and E.20 highlight the relatively strong management and administrative linkages that exist within the local sites as well as weak linkages across sites. They also highlight the supervisory and management chains that exist within the National Material Competency. These linkages can be expected due to supervisory controls and linkages between the local site level 4 and the site level 3 supervisors. The comparison between Figures E.18 which shows tight overall clustering, with Figure E.20 show the differences when frequencies of monthly, weekly and daily are applied that scatter the sites in a much more distributed fashion. Clearly, the interactions and exchange of knowledge occur at the local level within the site vice via the national competency organizational chain. These charts indicate that more effort is required to integrate the national competency leadership concept into each of the sites.

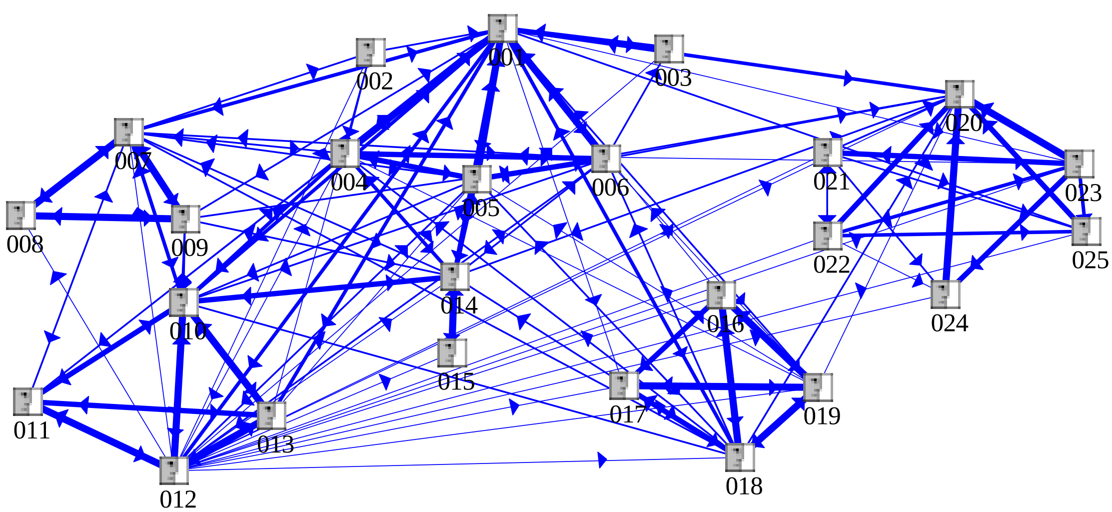

Figure E.17 National Level 3 All Responses: Management and Administration

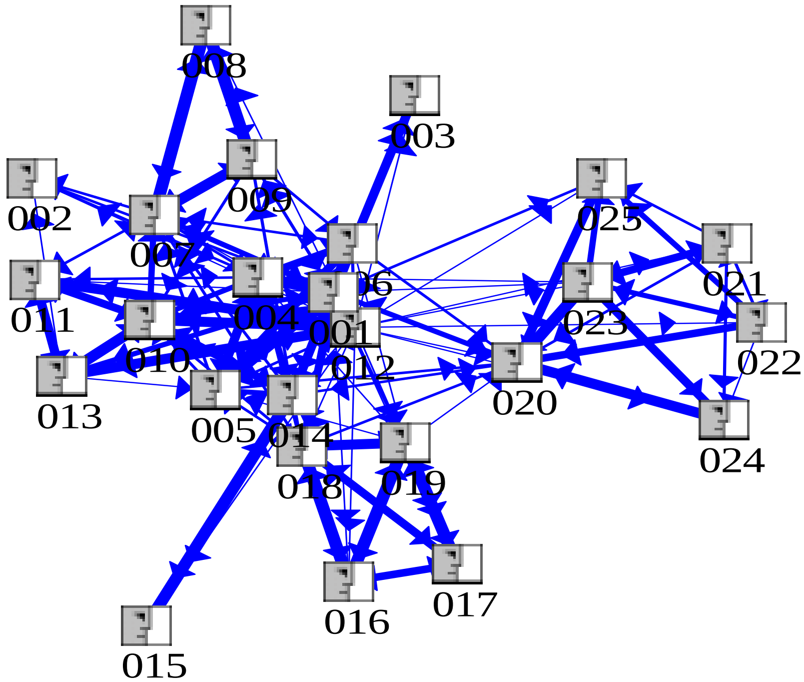

Figure E.18 National Level 3 All Responses: Management and Administration

"Arranged"

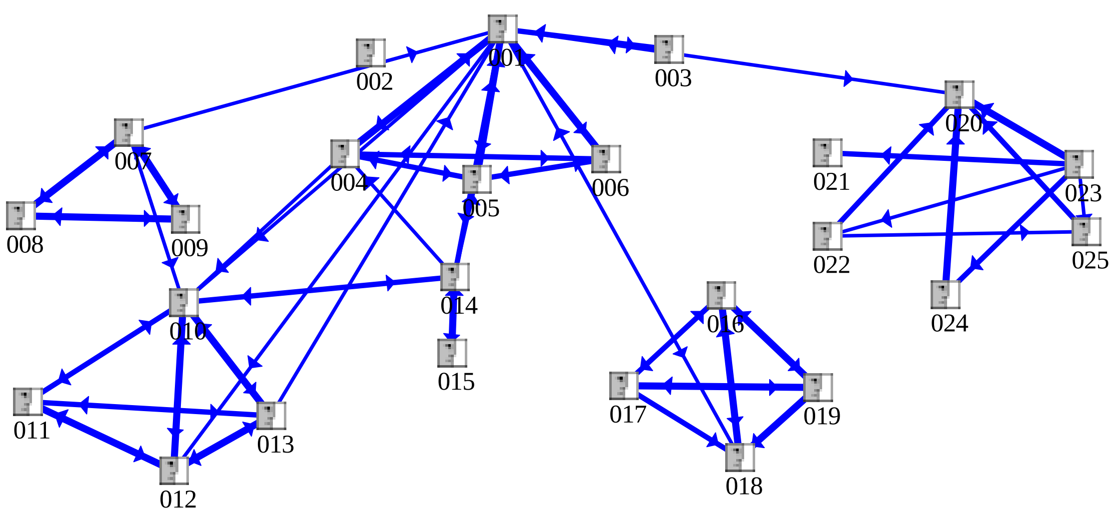

Figure E.19 National Level 3 Responses 3-5: Management and Administration

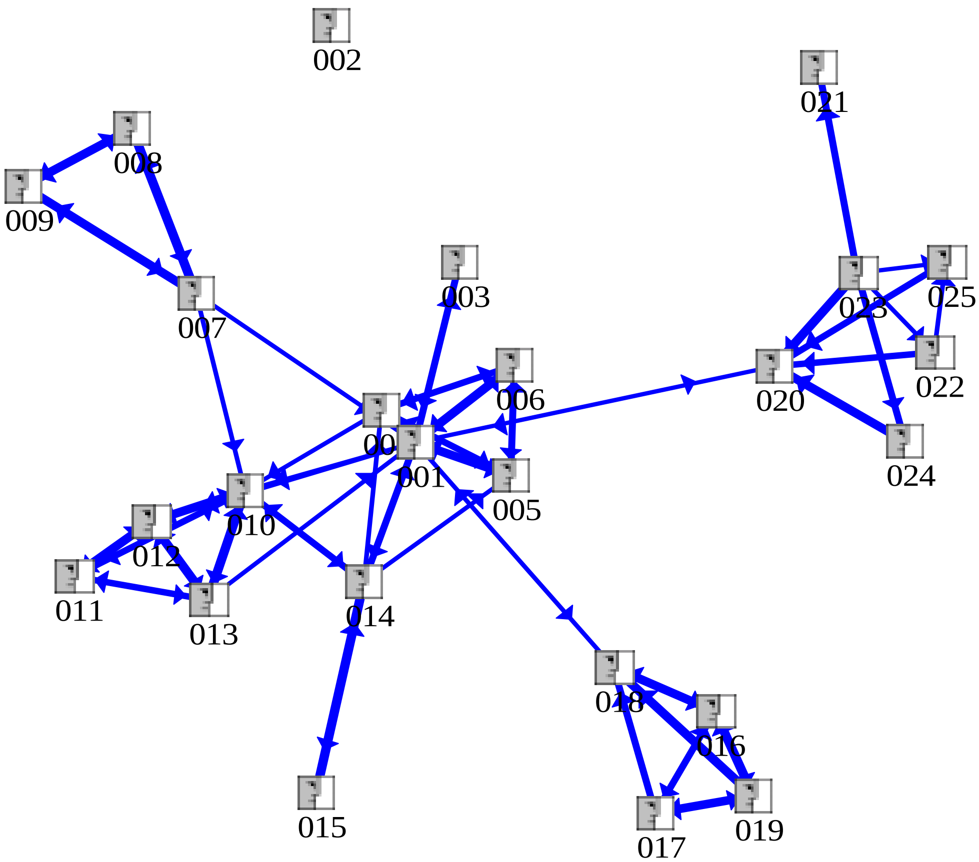

Figure E.20 National Level 3 Responses 3-5: Management and Administration

"Arranged"

F. Level 3 Strategic Planning

Figures E.21 through E.24 highlight the interconnections and flow of knowledge for strategic planning. This question evoked a moderate response for the National Level 3 Materials Competency as a whole, which was expected. The National Materials Competency leadership should evaluate the need for stronger strategic planning in competency operations. Feedback from MMB members indicates a desire to improve strategic planning knowledge flow, however, the demands for critical item responses such as failure analysis and nondestructive inspection bulletins, short term budgetary challenges, and high expectations for productivity performance tends to create a more tactically oriented culture. Recent initiatives regarding strategic planning at the Air Vehicle Department level are expected to enhance the emphasis on a more strategically oriented culture. Formal strategic planning efforts have recently been initiated in: aging aircraft for air vehicles, unmanned aerial vehicles, and competency management. Node 001, the National Level 3 Materials Competency leader is central, as shown in the star topology, to the flow of knowledge regarding strategic planning. This is also expected, as shown in Figure E.24 for monthly, weekly and daily frequencies because the National Level 3 Competency leader is held most responsible for strategic activities. The high dispersion of the "arranged" Figure E.24 indicates weak linkages and infrequent flow of knowledge and expertise for strategic planning. Also, Figures E.23 and E.24 show three isolates that exist which indicates that they are not frequently involved in strategic planning activities, even at their local site.

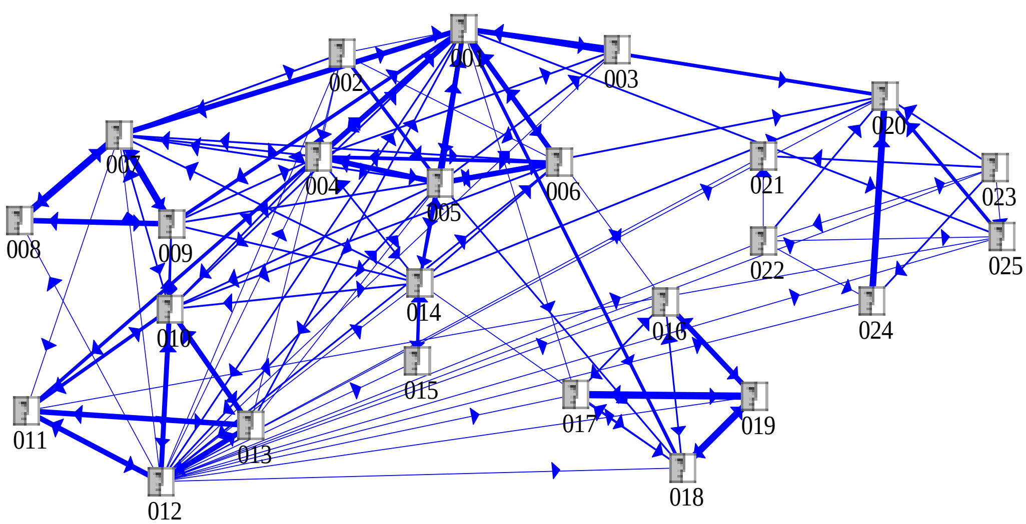

Figure E.21 National Level 3 All Responses: Strategic

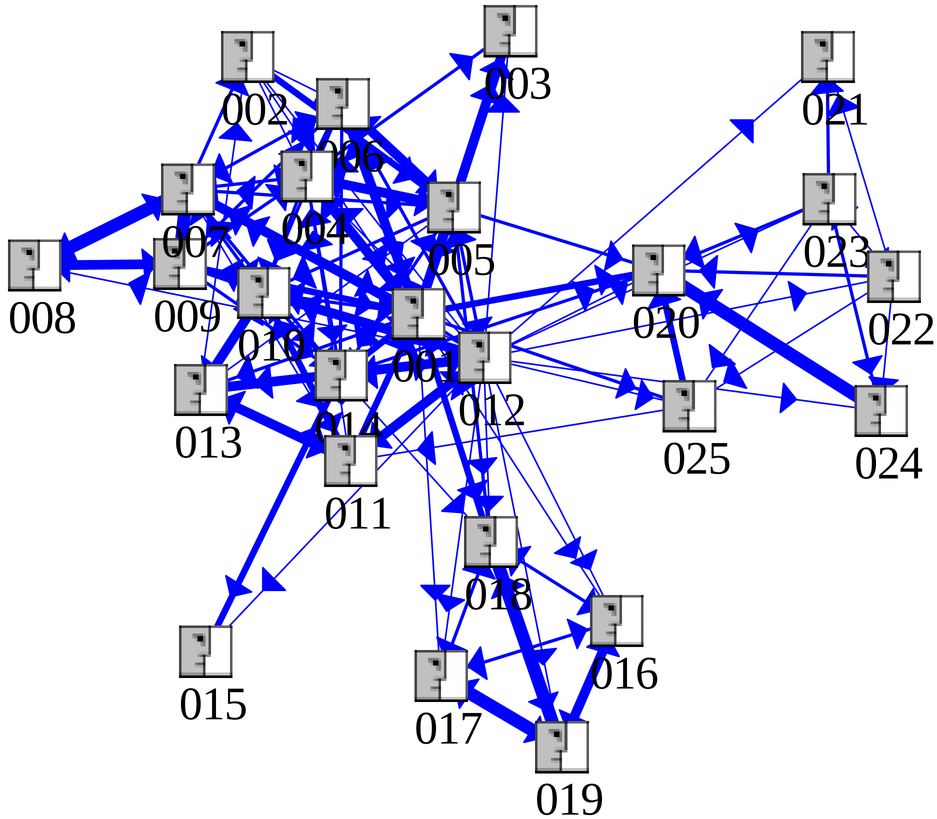

Figure E.22 National Level 3 All Responses: Strategic "Arranged"

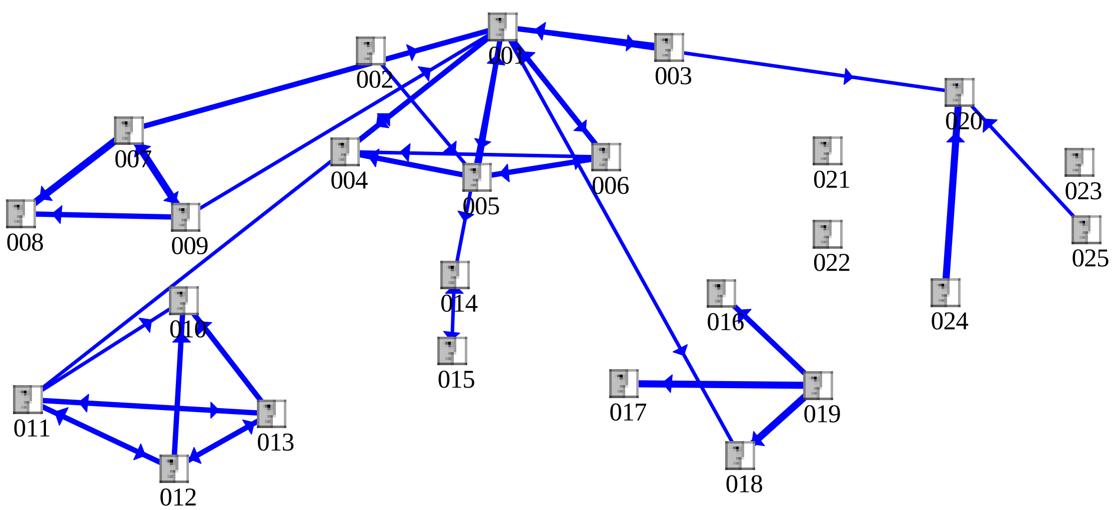

Figure E.23 National Level 3 Responses 3-5: Strategic

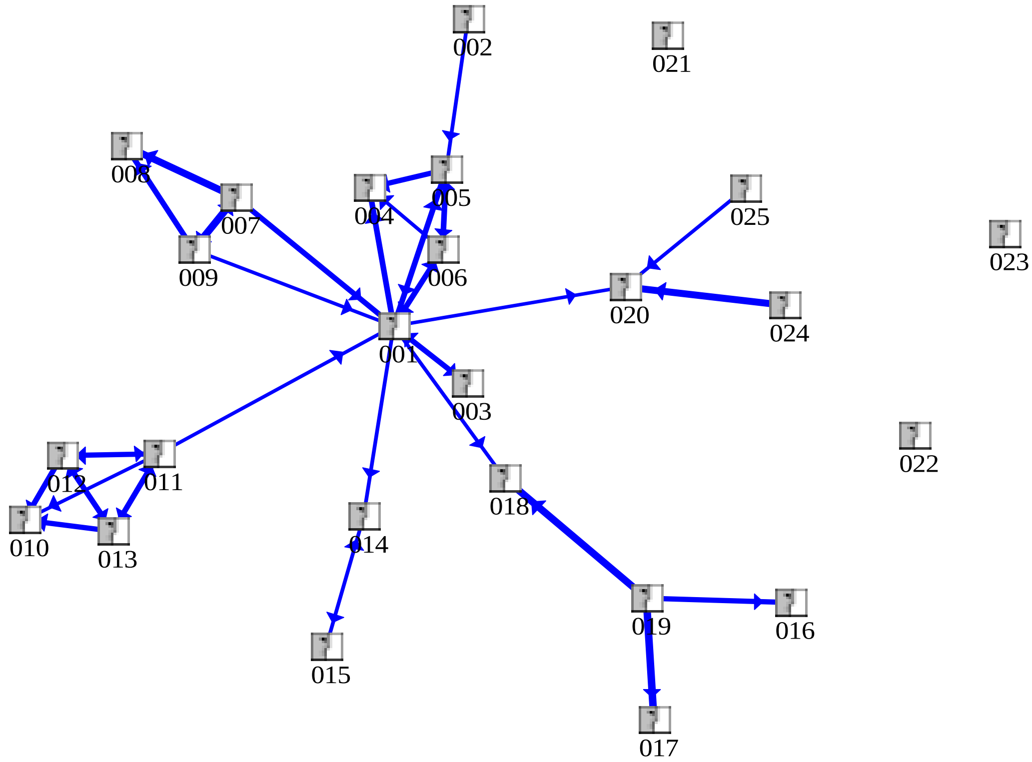

Figure E.24 National Level 3 Responses 3-5: Strategic “Arranged”

APPENDIX F

National Level 4 Supplemental Results and Analysis

The National Metals and Ceramics Level 4 Competency is very infrequently linked in the area of science and technology as shown in Figure F.1. Two nodes in this sociogram are isolates indicating no interactions at two competency sites: Lakehurst and China Lake. Very limited cross-site flow of knowledge is evident in this scenario

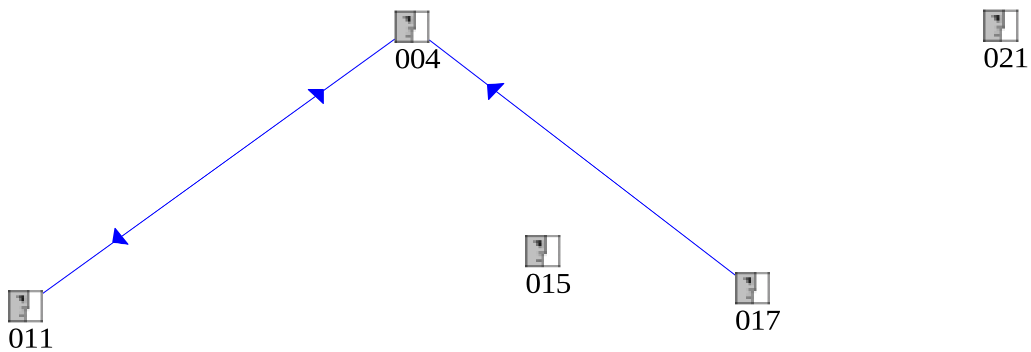

Figure F.1 National Level 4 Metals/Ceramics All Responses: S&T

In the area of acquisition, the National Metals/Ceramics Competency has very limited flow of knowledge and expertise. Two-way connectivity is evident between the Jacksonville site level 4 and the National Metals/Ceramics Level 4 Competency leader, however, three isolates exist with no apparent flow of knowledge or expertise from or to North Island, Lakehurst, or China Lake. Similarly, very low levels of interaction exist in in-service engineering including no apparent direct-out knowledge flow from the National Metals/Ceramics Level 4 Competency leader, rather, knowledge is flowing in from only two nodes and no knowledge flow is evident to the National Metals/Ceramics Level 4 Competency leader from Lakehurst or China Lake. In Figures F.2, F.3, F.4, F.5 and F.6, a single two-way linkage, albeit weak, exists between Patuxent River and Jacksonville. Overall, the National Metals/Ceramics Competency should improve their social capital, and further build trust and a sense of community among the leadership.

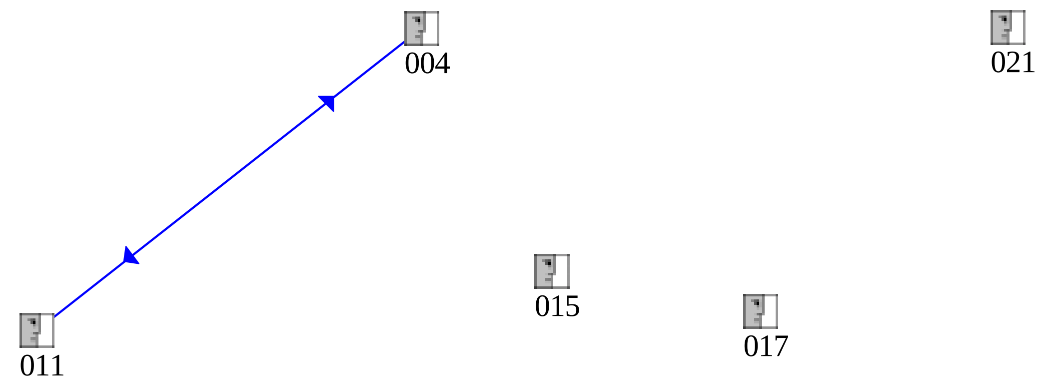

Figure F.2 National Level 4 Metals/Ceramics All Responses: Acquisition

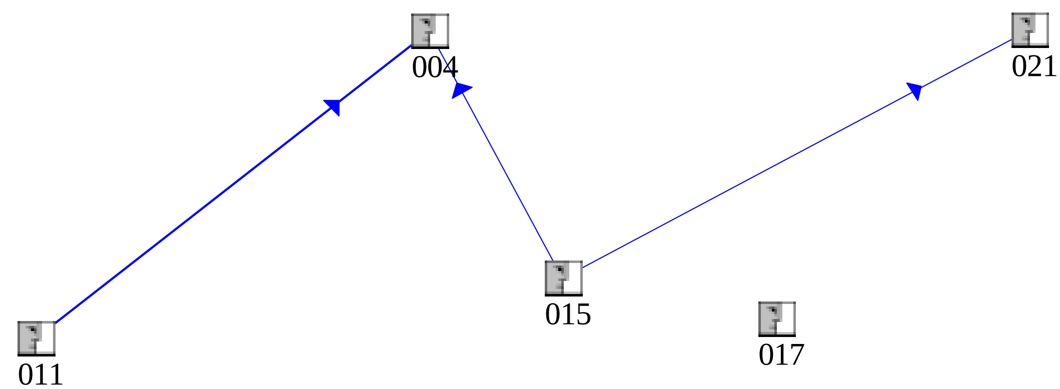

Figure F.3 National Level 4 Metals/Ceramics All Responses: In-Service Engineering

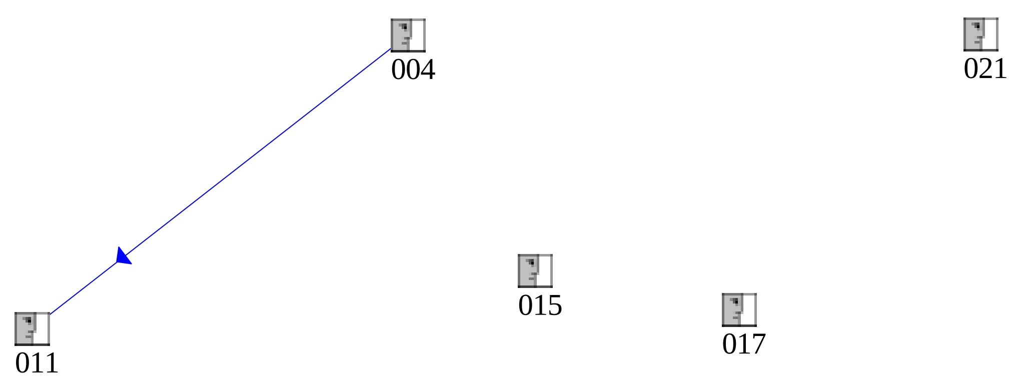

Figure F.4 National Level 4 Metals/Ceramics All Responses: Business Development

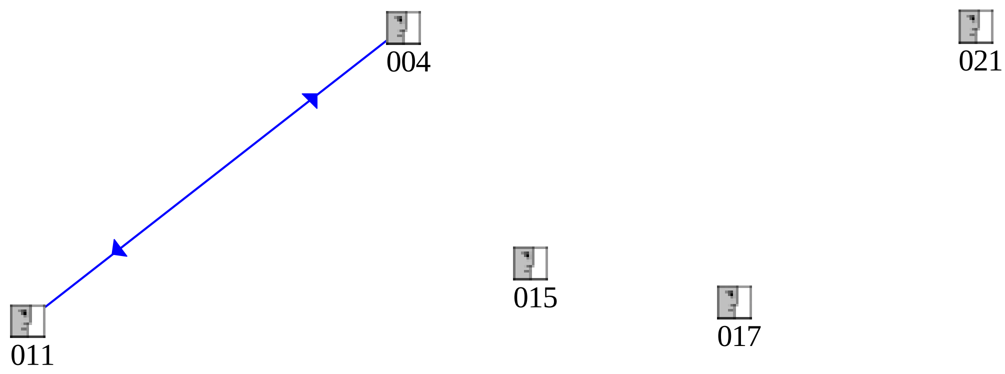

Figure F.5 National Level 4 Metals/Ceramics All Responses: Management

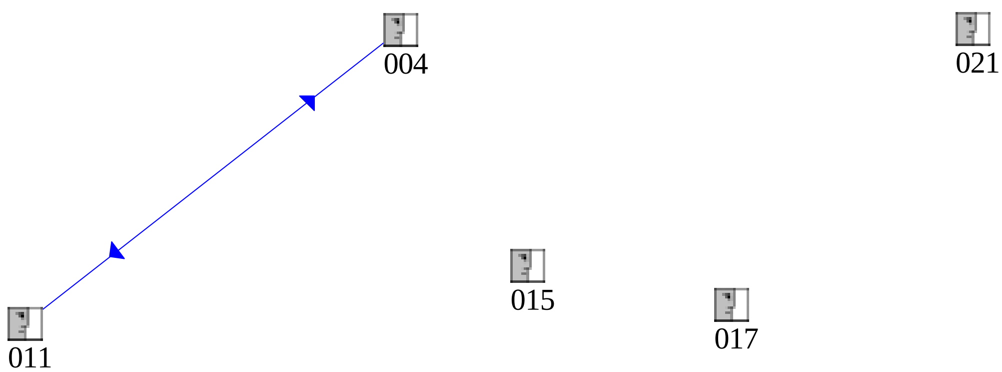

Figure F.6 National Level 4 Metals/Ceramics All Responses: Strategic Planning

Figures F.7 through F.12 display the National Level 4 Industrial/ Operational Chemicals Competency results for the six individual questions. Figure F.7 provides the National Level 4 Industrial/Operational Chemicals All Responses for S&T. Five one-way flows are evident and only two linkages are shown for two-way flow between the six nodes in the scenario. Only a single one-way flow exists to China Lake with no outgoing flows from China Lake identified. Similarly, North Island only has one incoming flow and no outgoing flows of knowledge and expertise for this scenario. Lakehurst has only two incoming flows and no outgoing flows. Figure F.8 shows the National Level 4 Industrial/Operational Chemicals All Responses for Acquisition. Within this network on only one two-way flow exists between Patuxent River and Jacksonville. Cherry Point, North Island and China Lake are both receiving a single one-way flow with no outgoing flows. No linkages exist between the National Level 4 Competency leader and the Site Level 3's at Cherry Point, North Island and China Lake. Figure F.9 provides the National Level 4 Industrial/Operational Chemicals All Responses for In-Service Engineering which shows a relatively high level of connectivity. This scenario shows three two-way flows with every site connected by at least two links. Figure F.10 provides the National Level 4 Industrial/Operational Chemicals All Responses for Business Development, which closely resembles Figure F.8 with only one two-way linkage and three sites with a single incoming flow and no outgoing flows. Again, the National Level 4 is not directly connected to the Site Level 4's at three sites. F.11 provides the National Level 4 Industrial/Operational Chemicals All Responses for Management, which consists of two two-way flows and three single incoming flows without any outgoing flows at sites Cherry Point, North Island and China Lake. Figure F.12 provides the National Level 4 Industrial/Operational Chemicals All Responses for Strategic Planning with only one two-way flow and three single incoming flows without any outgoing flows at sites Cherry Point, North Island and China Lake.

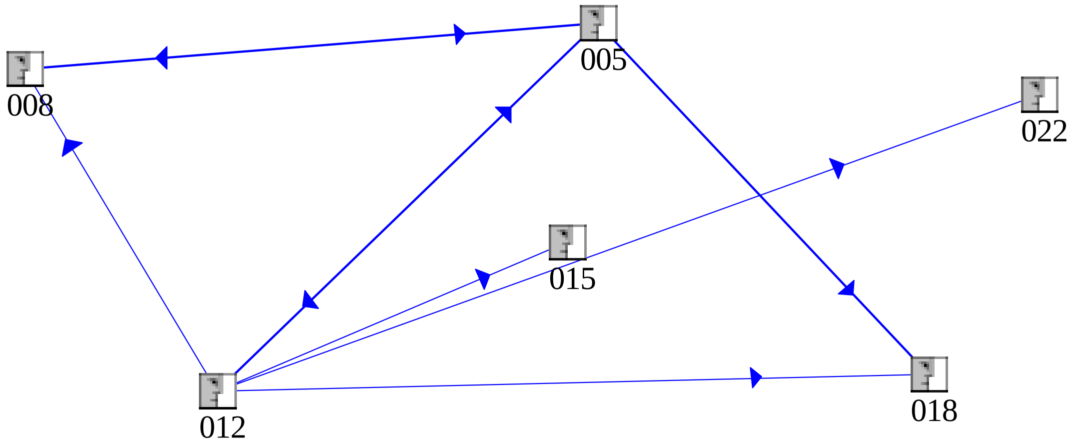

Figure F.7 National Level 4 Industrial/Operational Chemicals All Responses: S&T

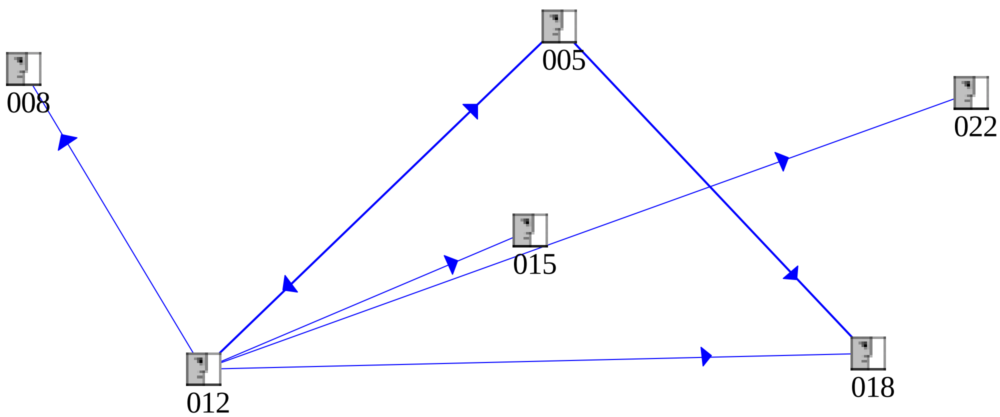

Figure F.8 National Level 4 Industrial/Operational Chemicals All Responses: Acquisition

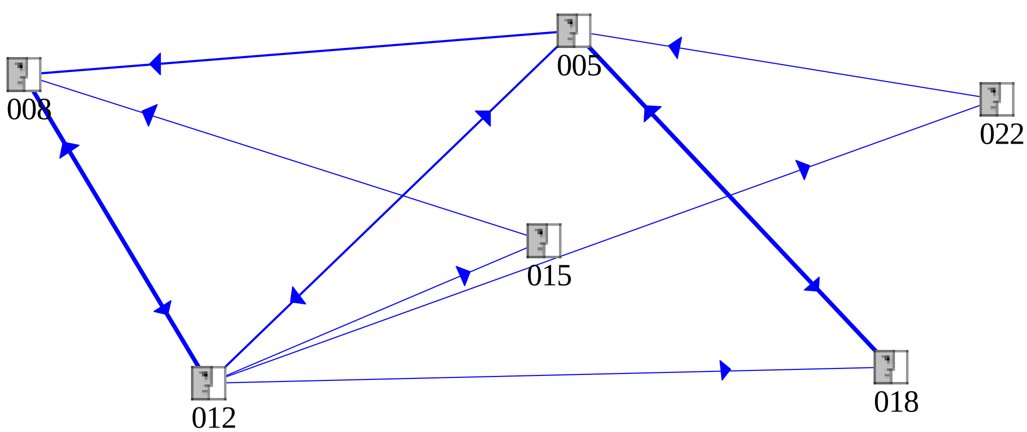

Figure F.9   National Level 4 Industrial/Operational Chemicals All Responses: In-Service

Engineering

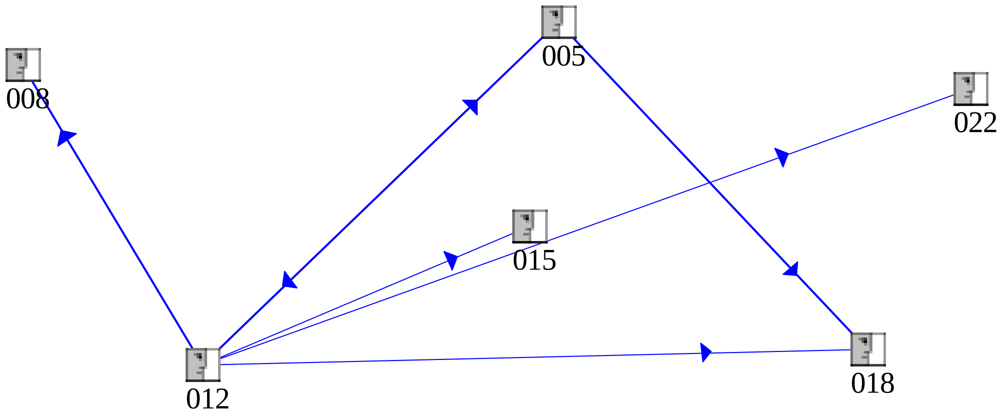

Figure F.10 National Level 4 Industrial/Operational Chemicals All Responses:

Business Development

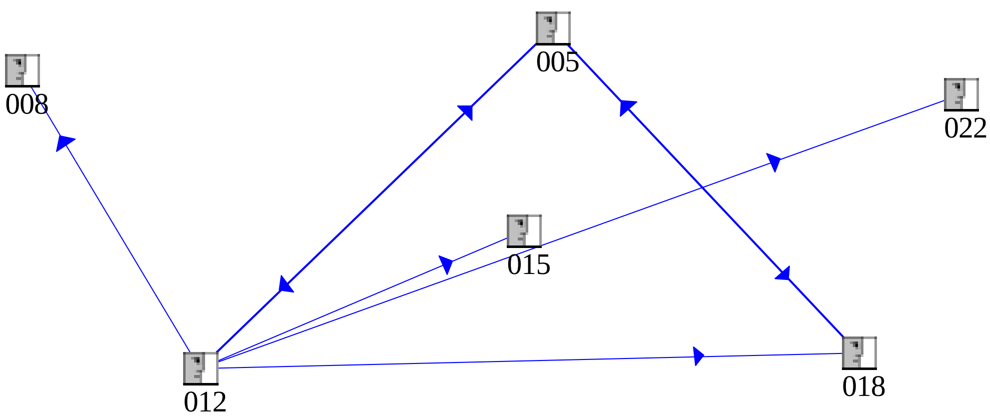

Figure F.11 National Level 4 Industrial/Operational Chemicals All Responses:

Management

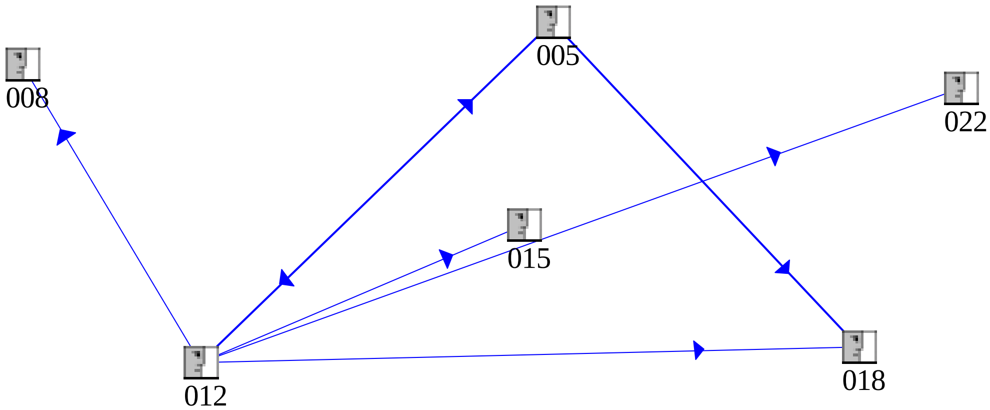

Figure F.12 National Level 4 Industrial/Operational Chemicals All Responses: Strategic Planning

Figures F.13 through F.18 provide the National Level 4 Nondestructive Inspection responses for the six individual questions. These figures show a significant lack of connectivity and cohesion. Figure F.13, F.15, F.16, and F.18 display two-way and one-way connections only between Patuxent River and Jacksonville, leaving the other sites isolated. Figure F.14 and F.17 are similar and show the addition of one-way incoming flows from Lakehurst and Jacksonville to Patuxent River.

Figure F.13 National Level 4 Nondestructive Inspection All Responses: S&T

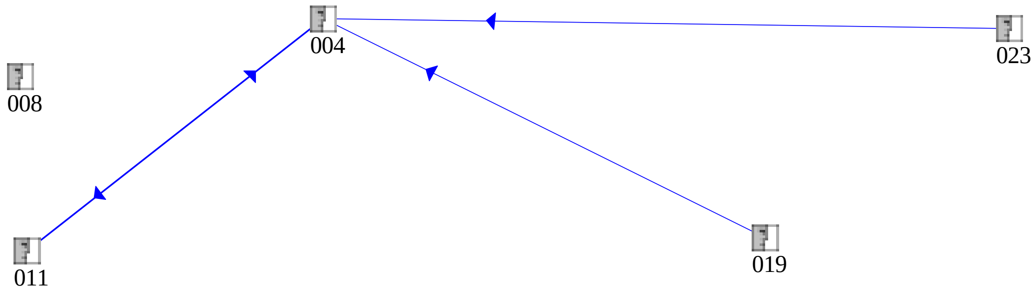

Figure F.14 National Level 4 Nondestructive Inspection All Responses: Acquisition

Figure F.15 National Level 4 Nondestructive Inspection All Responses:

In-Service Engineering

Figure F.16 National Level 4 Nondestructive Inspection All Responses:

Business Development

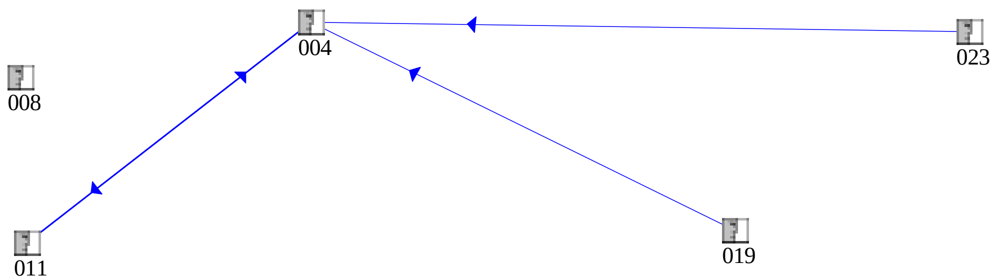

Figure F.17 National Level 4 Nondestructive Inspection All Responses: Management

Figure F.18 National Level 4 Nondestructive Inspection All Responses: Strategic Planning

Figures F.19 through F.24 provide the National Level 4 Polymers/Composites responses for the six individual questions. These figures show a total of six two-way flows with nodes from North Island and China Lake receiving only a single one-way flow. Also, Lakehurst is only receiving a one-way flow in Figures F.19, F.20, and F.23 with no outgoing flows and the National Level 4 Competency leader is not directly connected to North Island, Lakehurst or China Lake Site Level 4 Competency leaders for these scenarios.

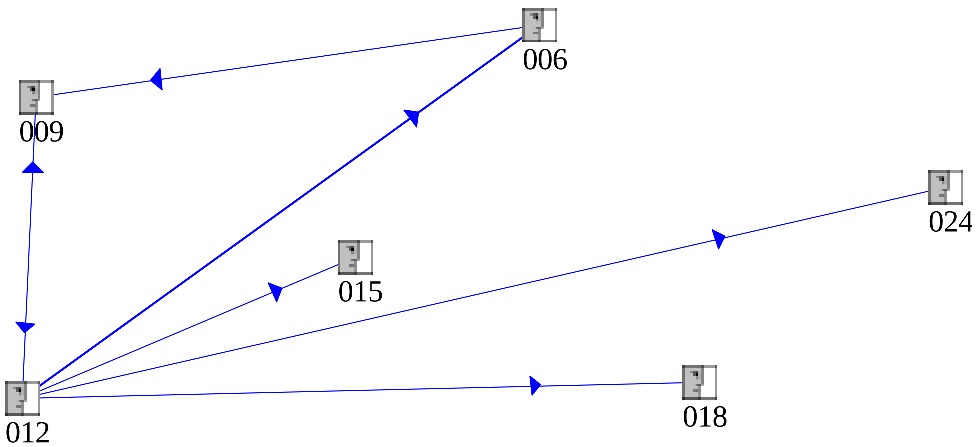

Figure F.19 National Level 4 Polymers/Composites All Responses: S&T

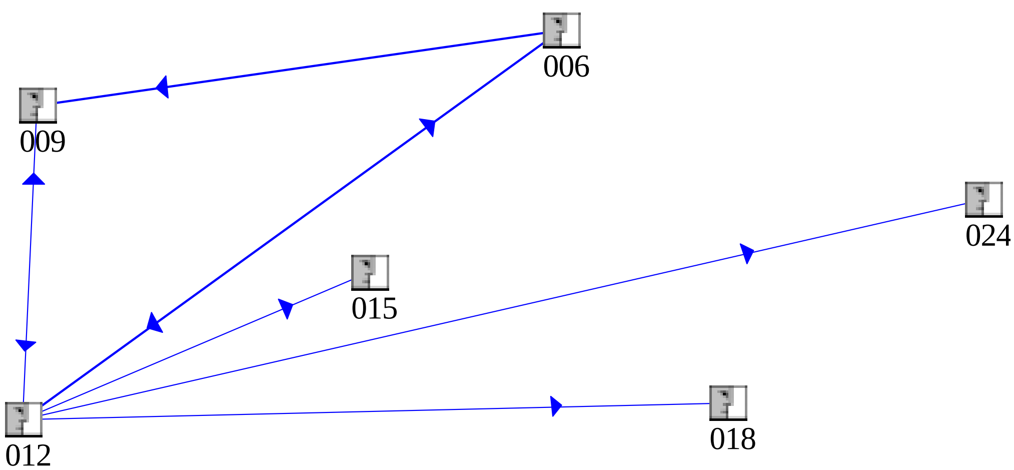

Figure F.20 National Level 4 Polymers/Composites All Responses: Acquisition

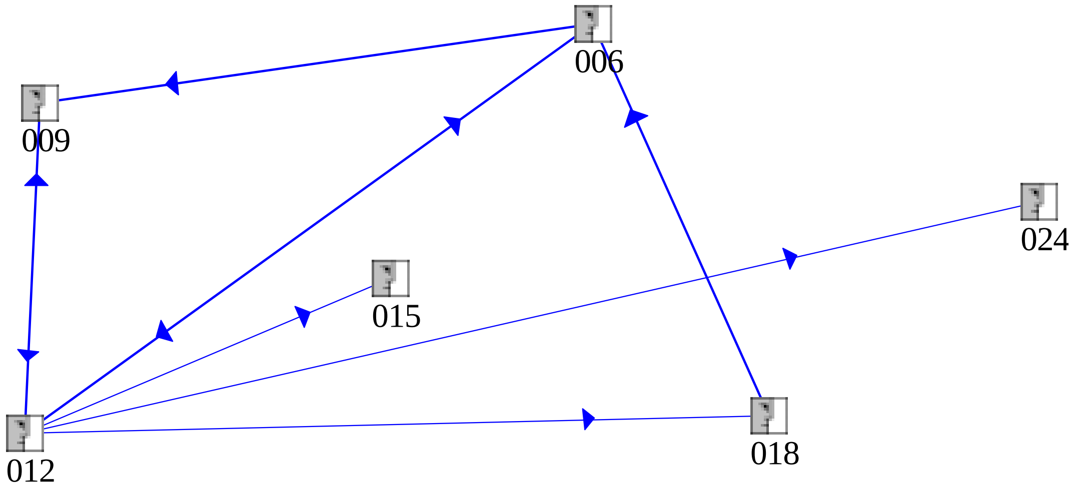

Figure F.21 National Level 4 Polymers/Composites All Responses: In-Service Engineering

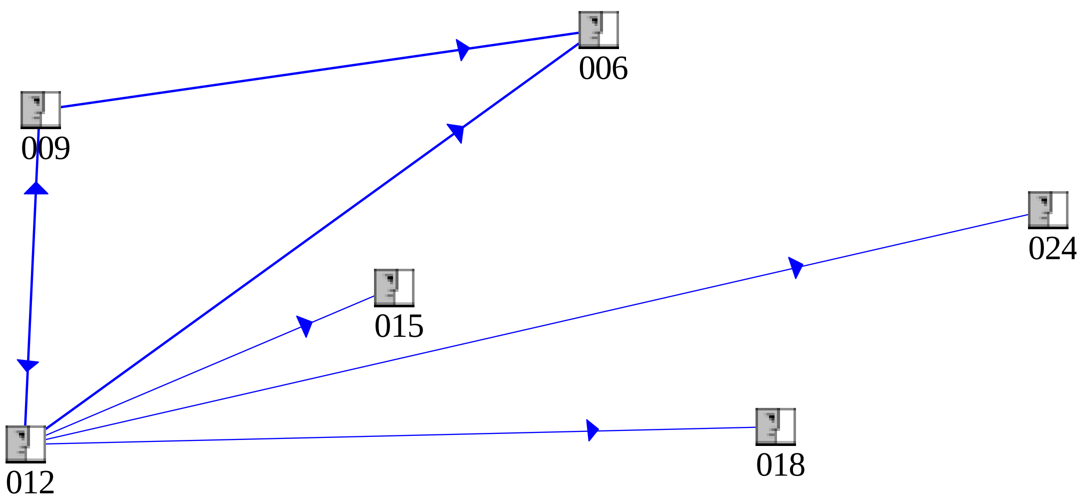

Figure F.22 National Level 4 Polymers/Composites All Responses: Business Development

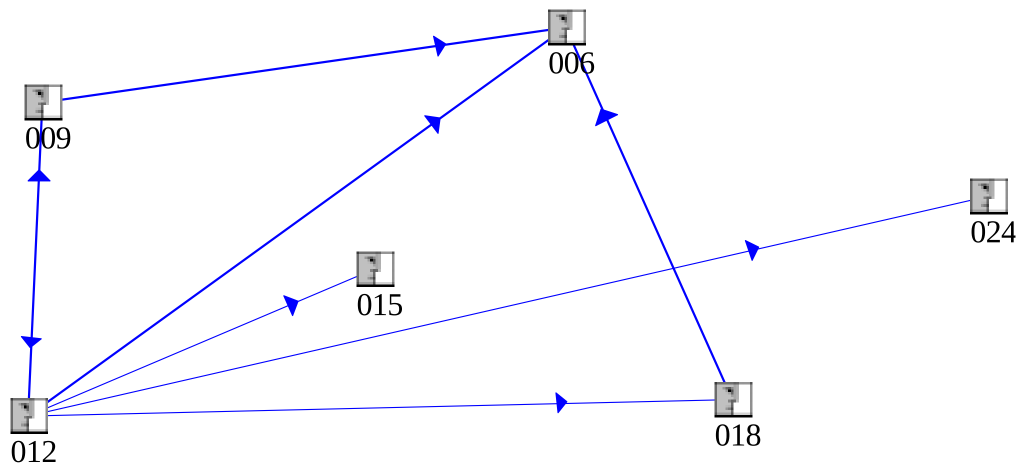

Figure F.23 National Level 4 Polymers/Composites All Responses: Management

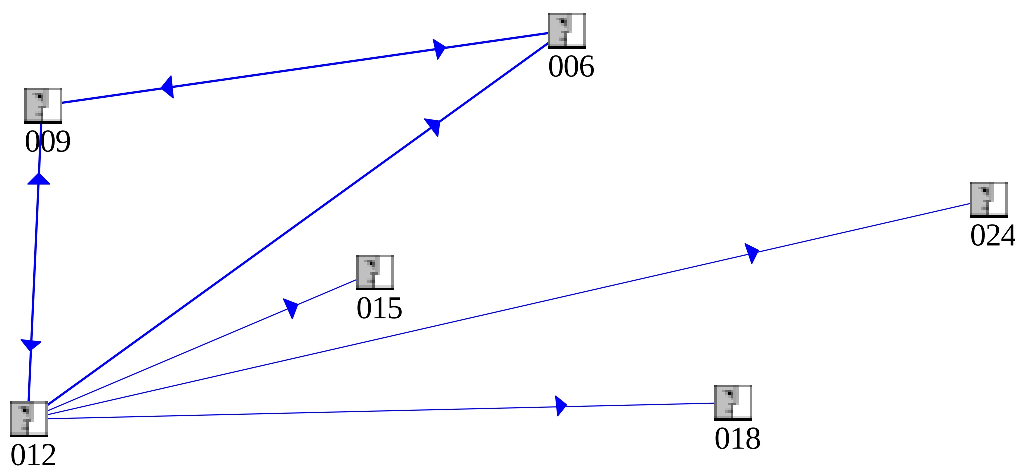

Figure F.24 National Level 4 Polymers/Composites All Responses: Strategic Planning

Figures F.25 through F.30 provide the National Level 4 Analytical Chemistry and Test All Responses for the six questions. This National Level 4 Competency exhibits very few linkages and is largely operating as a disconnected entity. No two-way flows exist within any of the six scenarios and members are highly isolated. All flows that do exist, exist only with the National Level 4 with no flows existing between the Site Level

4 Competency leaders. This situation needs further improvement to increase overall linkages and reduce the dependency on the National Level 4 leader for the flow of knowledge and expertise.

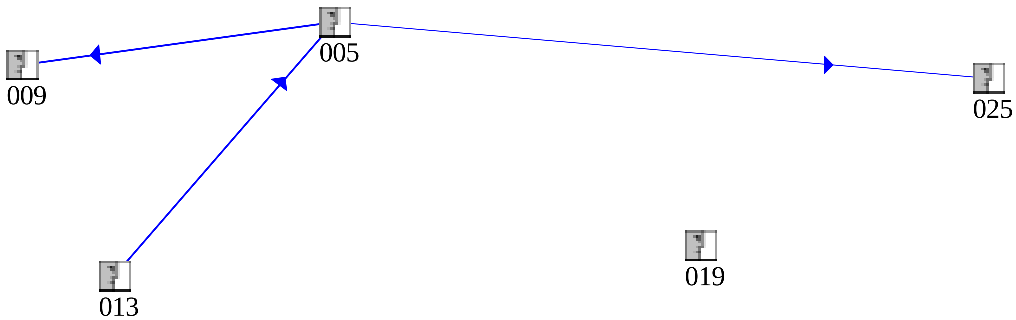

Figure F.25   National Level 4 Analytical Chemistry and Test All Responses: S&T

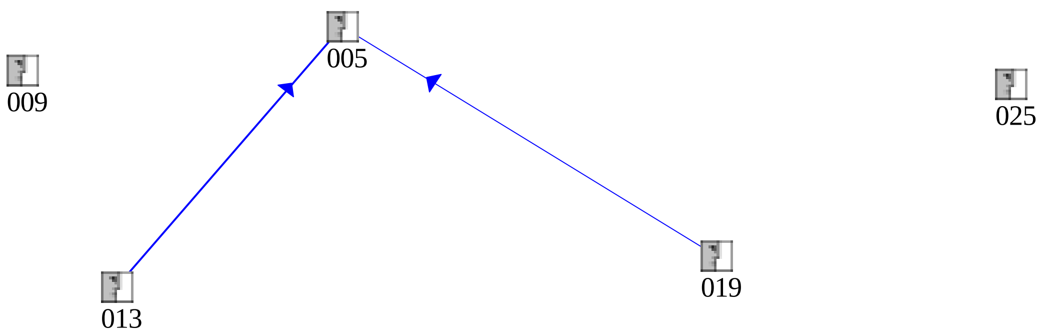

Figure F.26   National Level 4 Analytical Chemistry and Test All Responses: Acquisition

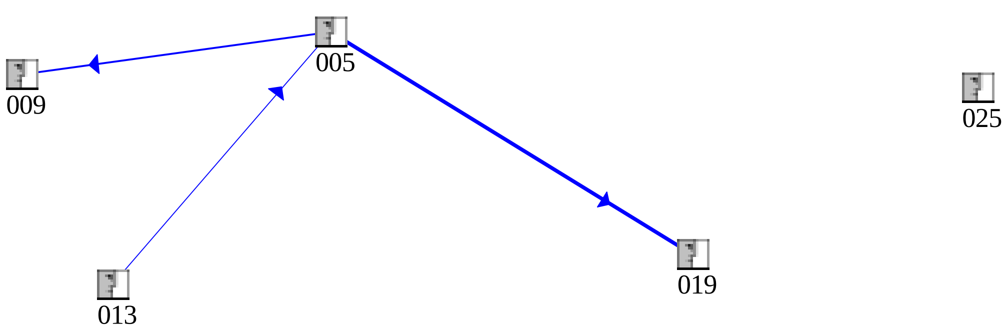

Figure F.27   National Level 4 Analytical Chemistry and Test All Responses:

In-Service Engineering

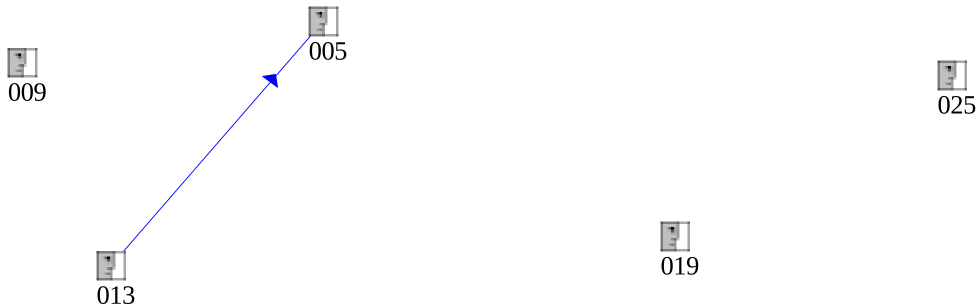

Figure F.28 National Level 4 Analytical Chemistry and Test All Responses: Business Development

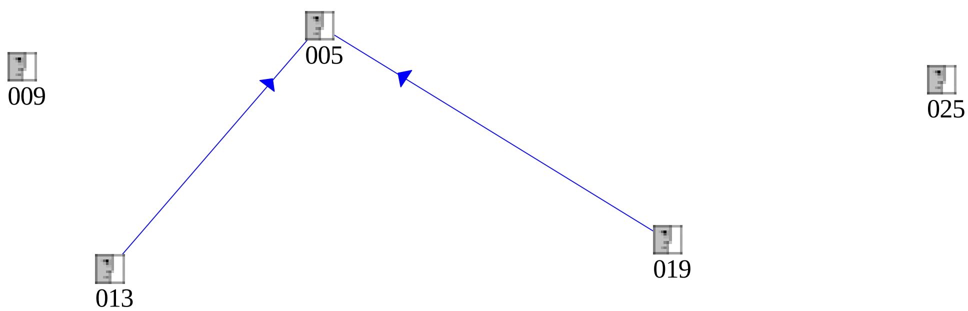

Figure F.29 National Level 4 Analytical Chemistry and Test All Responses: Management

Figure F.30 National Level 4 Analytical Chemistry and Test All Responses: Strategic Planning

Figures F.31 through F.36 provide responses for the National Level 4 Corrosion and Wear Competency to the six questions. This National Level 4 Competency exhibits only one two-way flow with a single isolate at Lakehurst across these scenarios. Only one linkage exists between Site Level 4 leaders creating a strong hub at the National Level 4 leader node. To improve connectivity, flows should be further developed between the sites with substantially more two-way flows of expertise and knowledge.

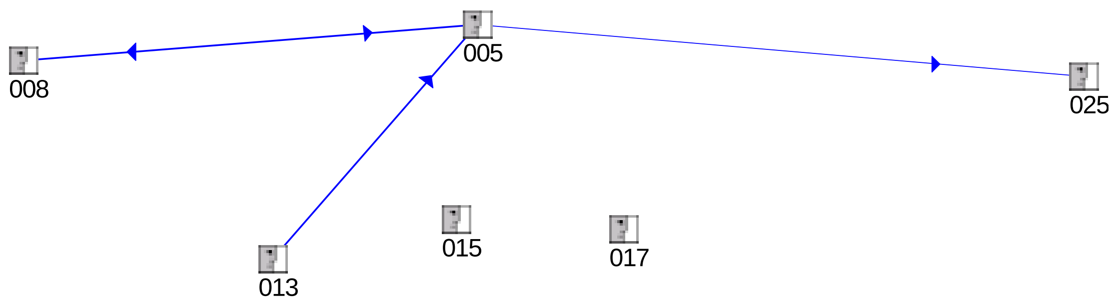

Figure F.31   National Level 4 Corrosion and Wear All Responses: S&T

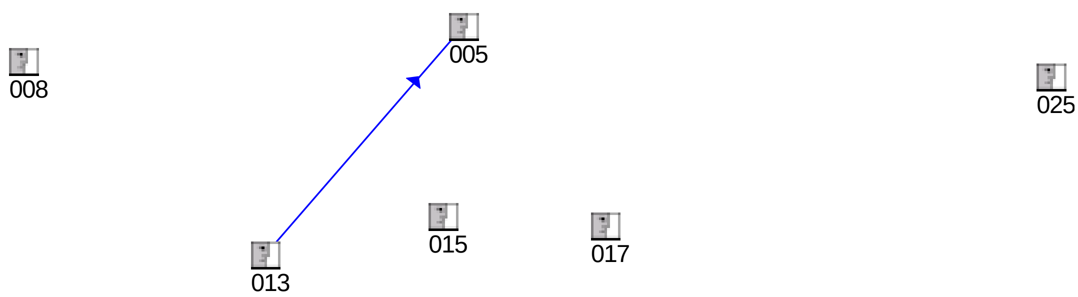

Figure F.32   National Level 4 Corrosion and Wear All Responses: Acquisition

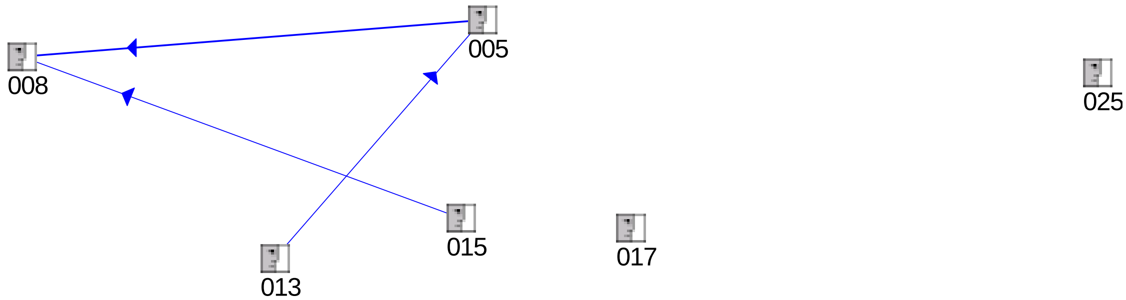

Figure F.33   National Level 4 Corrosion and Wear All Responses:

In-Service Engineering

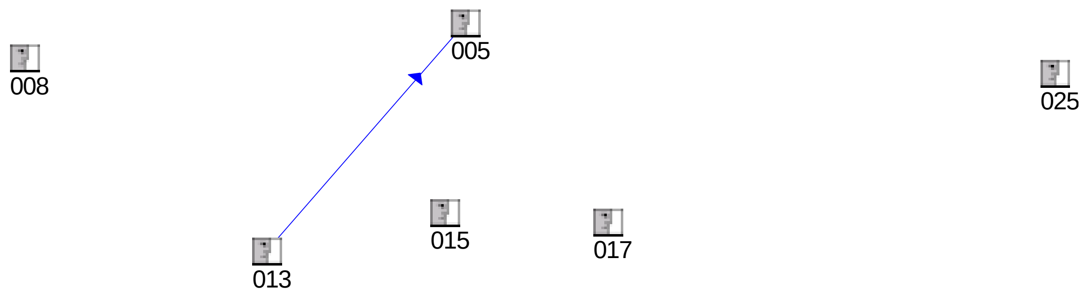

Figure F.34 National Level 4 Corrosion and Wear All Responses:

Business Development

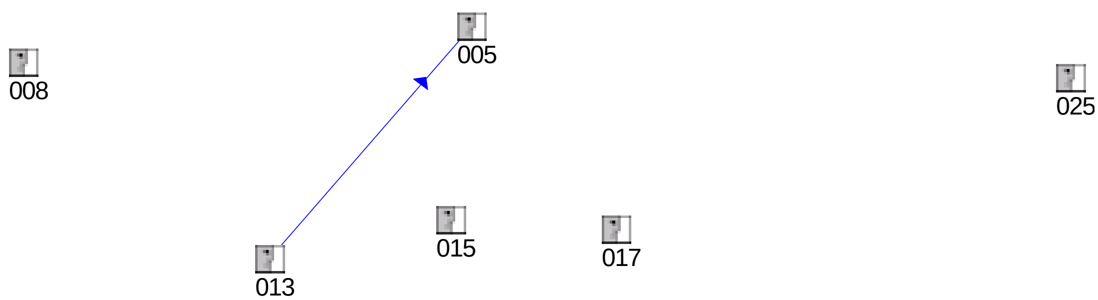

Figure F.35 National Level 4 Corrosion and Wear All Responses: Management

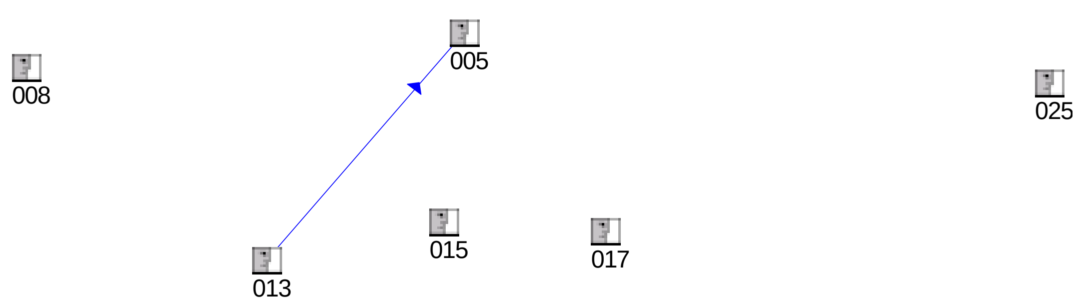

Figure F.36 National Level 4 Corrosion and Wear All Responses: Strategic Planning

APPENDIX G
SNA DATABASE METRICS (INFLOW DATA OUTPUT)

The data in Appendix G provides the specific metrics generated by InFlow 3.0 for each node included in the survey for a node-by-node analysis. The metrics generated provide data for each scenario in descending order for each node.

Level 3 All Questions
Network Centrality...

NETWORK
Q1
Q2
Q3
Q4
Q5
Q6

Group A
- -
Membership ALL

Group Size 25
Potential Ties 600
Actual Ties 240
Density 40%

Computing geodesics
240 paths of length 1
920 paths of length 2
368 paths of length 3
0 paths of length 4

Group A : Degrees (Out)

1.000	012
0.875	001
0.667	005
0.625	014
0.542	020
0.458	004
0.458	006
0.458	018
0.417	007
0.417	010
0.417	019
0.375	002
0.375	011
0.333	009
0.333	023
0.292	003
0.250	008
0.250	013
0.250	022
0.250	025
0.208	015
0.208	021
0.208	024
0.167	016
0.167	017
0.400	AVERAGE
0.652	CENTRALIZATION

Group A : Degrees (In)

0.708	001
0.667	004
0.667	005
0.583	006
0.583	010
0.583	020
0.542	014
0.500	007
0.458	002
0.458	012
0.375	009
0.375	011
0.333	003

0.333	018
0.333	021
0.333	025
0.292	008
0.292	019
0.292	022
0.292	023
0.250	013
0.250	024
0.208	016
0.208	017
0.083	015
0.400	AVERAGE
0.335	CENTRALIZATION

Group A : Betweeness (White & Borgatti) : Uniform

0.156	001
0.113	012
0.104	020
0.076	005
0.058	014
0.044	004
0.023	018
0.022	011
0.020	006
0.019	023
0.018	010
0.018	019
0.013	007
0.011	002
0.011	025
0.009	021
0.007	022
0.005	008
0.004	009
0.002	016
0.001	003
0.001	013
0.001	015
0.000	017
0.000	024
0.029	AVERAGE
0.132	CENTRALIZATION

Group A : Closeness (Out)

1.000	012
0.889	001
0.750	005
0.727	014
0.686	020
0.649	004
0.649	006
0.649	018
0.632	010
0.632	019
0.615	002
0.615	007
0.615	011
0.600	009
0.585	003
0.571	008
0.571	013
0.571	023
0.522	015
0.522	022
0.522	025
0.511	016
0.453	017
0.453	021
0.453	024
0.618	AVERAGE
0.814	CENTRALIZATION

Group A : Closeness (In)

0.774	001
0.750	004
0.750	005
0.706	006
0.706	020
0.686	014
0.667	010
0.632	007
0.615	002
0.615	011
0.615	012
0.600	003

0.600	018
0.585	021
0.585	025
0.571	009
0.571	019
0.571	022
0.571	023
0.533	024
0.522	013
0.511	008
0.500	016
0.500	017
0.453	015
0.608	AVERAGE
0.354	CENTRALIZATION

Group A : Power (Out)

0.556	012
0.522	001
0.413	005
0.395	020
0.393	014
0.347	004
0.336	018
0.334	006
0.325	010
0.325	019
0.319	011
0.314	007
0.313	002
0.302	009
0.295	023
0.293	003
0.288	008
0.286	013
0.266	025
0.265	022
0.261	015
0.256	016
0.231	021
0.227	017
0.226	024
0.324	AVERAGE

Group A : Power (In)

0.465	001
0.413	005
0.405	020
0.397	004
0.372	014
0.364	012
0.363	006
0.342	010
0.322	007
0.319	011
0.313	002
0.312	018
0.301	003
0.298	025
0.297	021
0.295	019
0.295	023
0.289	022
0.288	009
0.267	024
0.261	013
0.258	008
0.251	016
0.250	017
0.227	015
0.319	AVERAGE

NETWORK
Q1
Q2
Q3
Q4
Q5
Q6

Group A

- -

Membership All

Group Size 25
Potential Ties 600
Actual Ties 240
Density 40%

Computing geodesics
240 paths of length 1
920 paths of length 2
368 paths of length 3
0 paths of length 4

Group A : Reach (Out) - 2 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	018
1.000	019
1.000	020
0.958	007
0.917	023
0.875	015
0.875	016
0.833	022
0.833	025
0.625	017
0.583	021
0.583	024
0.923	AVERAGE

Group A : Reach (In) - 2 Steps

1.000	001
1.000	003
1.000	004
1.000	005
1.000	006
1.000	011
1.000	014
1.000	018
1.000	020
0.958	019
0.958	021
0.958	022
0.958	023
0.958	025
0.917	002
0.917	007
0.917	010
0.917	012
0.875	009
0.875	024
0.833	013
0.792	016
0.792	017
0.750	008
0.708	015
0.923	AVERAGE

Group A : Reach (Out) - 3 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	021
1.000	022
1.000	023
1.000	024
1.000	025
1.000	AVERAGE

Group A : Reach (In) - 3 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	021
1.000	022
1.000	023
1.000	024
1.000	025
1.000	AVERAGE

Group A : Reach (Out) - 4 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	021
1.000	022
1.000	023
1.000	024
1.000	025
1.000	AVERAGE

Group A : Reach (In) - 4 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	021
1.000	022
1.000	023
1.000	024
1.000	025
1.000	AVERAGE

Group A : Reach (Out) - 5 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	021
1.000	022
1.000	023
1.000	024
1.000	025
1.000	AVERAGE

Group A : Reach (In) - 5 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	021
1.000	022
1.000	023
1.000	024
1.000	025
1.000	AVERAGE

Group A : Reach (Out) - 6 Steps

1.000	001
1.000	002
1.000	003

1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	021
1.000	022
1.000	023
1.000	024
1.000	025
1.000	AVERAGE

Group A : Reach (In) - 6 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	021
1.000	022
1.000	023
1.000	024
1.000	025
1.0	AVERAGE

Small World Metrics...

NETWORK
Q1
Q2
Q3
Q4
Q5
Q6

Group A

Group Size 25
Potential Ties 600
Actual Ties 240
Density 40%

Computing geodesics
240 paths of length 1
920 paths of length 2
368 paths of length 3
0 paths of length 4

Name	CC	Avg. Path Length	Shortcuts
001	0.41	1.13	0.00

002	0.73	1.63	0.00
003	0.93	1.71	0.00
004	0.51	1.54	0.00
005	0.50	1.33	0.00
006	0.63	1.54	0.00
007	0.66	1.63	0.00
008	0.62	1.75	0.00
009	0.83	1.67	0.00
010	0.65	1.58	0.00
011	0.69	1.63	0.00
012	0.37	1.00	0.00
013	0.90	1.75	0.00
014	0.57	1.38	0.00
015	0.53	1.92	0.20
016	0.80	1.96	0.00
017	0.77	2.21	0.00
018	0.67	1.54	0.00
019	0.69	1.58	0.00
020	0.52	1.46	0.00
021	0.61	2.21	0.00
022	0.71	1.92	0.00
023	0.64	1.75	0.00
024	0.83	2.21	0.00
025	0.64	1.92	0.17
-----------	----	---------------- ---------	
Overall	0.66	2.08	0.01

Network Centrality...

NETWORK
Q1

Group A

Group Size 25
Potential Ties 600
Actual Ties 158
Density 26%

Computing geodesics
158 paths of length 1
411 paths of length 2
405 paths of length 3
193 paths of length 4
28 paths of length 5
0 paths of length 6

Group A : Degrees (Out)

1.000	012
0.625	005
0.458	001
0.375	004
0.375	011
0.333	007
0.333	020
0.292	002
0.292	003
0.250	006
0.250	013
0.208	014
0.208	021
0.208	023
0.208	024
0.208	025
0.167	016
0.167	017
0.125	009
0.125	010
0.125	018
0.125	019
0.083	008
0.042	015
0.000	022
0.263	AVERAGE
0.801	CENTRALIZATION

Group A : Degrees (In)

0.500	001
0.458	002
0.417	004
0.417	005
0.333	003
0.333	010

0.333	020
0.250	006
0.250	007
0.250	011
0.250	014
0.250	022
0.250	025
0.208	009
0.208	012
0.208	013
0.208	016
0.208	017
0.208	018
0.208	019
0.208	021
0.208	023
0.208	024
0.167	008
0.042	015
0.263	AVERAGE
0.257	CENTRALIZATION

Group A : Betweeness (White & Borgatti) : Uniform

0.241	001
0.223	020
0.184	005
0.171	012
0.082	004
0.058	003
0.053	016
0.045	014
0.036	017
0.025	010
0.023	007
0.020	002
0.020	011
0.019	019
0.015	013
0.012	025
0.009	006
0.009	009
0.005	018
0.002	008
0.000	015
0.000	021
0.000	022
0.000	023
0.000	024
0.050	AVERAGE
0.199	CENTRALIZATION

Group A : Closeness (Out)

1.000	012
0.727	005
0.632	001
0.615	011
0.571	003
0.571	013
0.533	004
0.533	009
0.533	010
0.522	020
0.511	002
0.500	006
0.500	007
0.490	014
0.444	008
0.429	016
0.400	017
0.369	021
0.369	023
0.369	024
0.369	025
0.343	015
0.324	018
0.324	019
0.042	022
0.481	AVERAGE
1.105	CENTRALIZATION

Group A : Closeness (In)

0.421	022
0.414	001
0.375	003

0.375	004
0.369	002
0.364	005
0.364	020
0.348	010
0.338	006
0.338	007
0.338	014
0.338	016
0.338	017
0.338	018
0.333	025
0.329	013
0.329	019
0.312	011
0.300	021
0.300	023
0.300	024
0.296	009
0.296	012
0.293	008
0.238	015
0.335	AVERAGE
0.182	CENTRALIZATION

Group A : Power (Out)

0.586	012
0.455	005
0.436	001
0.373	020
0.318	011
0.315	003
0.308	004
0.293	013
0.279	010
0.271	009
0.267	014
0.265	002
0.262	007
0.254	006
0.241	016
0.223	008
0.218	017
0.191	025
0.185	021
0.185	023
0.185	024
0.172	019
0.171	015
0.164	018
0.021	022
0.266	AVERAGE

Group A : Power (In)

0.328	001
0.294	020
0.274	005
0.234	012
0.229	004
0.216	003
0.211	022
0.196	016
0.194	002
0.191	014
0.187	017
0.186	010
0.181	007
0.174	019
0.173	006
0.173	025
0.172	013
0.171	018
0.166	011
0.153	009
0.150	021
0.150	023
0.150	024
0.147	008
0.119	015
0.193	AVERAGE

Network Reach...

NETWORK

Q1

Group A
Group Size 25
Potential Ties 600
Actual Ties 158
Density 26%

Computing geodesics
158 paths of length 1
411 paths of length 2
405 paths of length 3
193 paths of length 4
28 paths of length 5
0 paths of length 6

Group A : Reach (Out) - 2 Steps

1.000	005
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
0.958	001
0.958	003
0.792	020
0.750	002
0.750	004
0.750	006
0.750	014
0.667	007
0.667	008
0.542	016
0.542	017
0.333	021
0.333	023
0.333	024
0.333	025
0.250	015
0.208	018
0.208	019
0.000	022
0.645	AVERAGE

Group A : Reach (In) - 2 Steps

0.958	001
0.875	003
0.792	004
0.792	020
0.708	002
0.708	005
0.708	016
0.708	017
0.708	018
0.708	025
0.667	006
0.667	007
0.667	010
0.667	014
0.667	019
0.625	013
0.583	011
0.542	008
0.542	009
0.542	012
0.542	022
0.500	021
0.500	023
0.500	024
0.250	015
0.645	AVERAGE

Group A : Reach (Out) - 3 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
0.958	016

0.958	020
0.792	015
0.792	017
0.792	021
0.792	023
0.792	024
0.792	025
0.625	018
0.625	019
0.000	022
0.877	AVERAGE

Group A : Reach (In) - 3 Steps

0.958	001
0.958	002
0.958	003
0.958	004
0.958	005
0.958	006
0.958	007
0.958	010
0.958	013
0.958	014
0.958	016
0.958	017
0.958	018
0.958	020
0.917	019
0.875	025
0.833	022
0.792	011
0.792	021
0.792	023
0.792	024
0.708	008
0.708	009
0.708	012
0.583	015
0.876	AVERAGE

Group A : Reach (Out) - 4 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	020
0.958	018
0.958	019
0.958	021
0.958	023
0.958	024
0.958	025
0.000	022
0.950	AVERAGE

Group A : Reach (In) - 4 Steps

1.000	022
0.958	001
0.958	002
0.958	003
0.958	004
0.958	005
0.958	006
0.958	007
0.958	008
0.958	009
0.958	010
0.958	011
0.958	012
0.958	013
0.958	014
0.958	016
0.958	017
0.958	018

0.958	019
0.958	020
0.958	021
0.958	023
0.958	024
0.958	025
0.708	015
0.950	AVERAGE

Group A : Reach (Out) - 5 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	021
1.000	023
1.000	024
1.000	025
0.000	022
0.960	AVERAGE

Group A : Reach (In) - 5 Steps

1.000	022
0.958	001
0.958	002
0.958	003
0.958	004
0.958	005
0.958	006
0.958	007
0.958	008
0.958	009
0.958	010
0.958	011
0.958	012
0.958	013
0.958	014
0.958	015
0.958	016
0.958	017
0.958	018
0.958	019
0.958	020
0.958	021
0.958	023
0.958	024
0.958	025
0.960	AVERAGE

Group A : Reach (Out) - 6 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	021

1.000	023
1.000	024
1.000	025
0.000	022
0.960	AVERAGE

Group A : Reach (In) - 6 Steps

1.000	022
0.958	001
0.958	002
0.958	003
0.958	004
0.958	005
0.958	006
0.958	007
0.958	008
0.958	009
0.958	010
0.958	011
0.958	012
0.958	013
0.958	014
0.958	015
0.958	016
0.958	017
0.958	018
0.958	019
0.958	020
0.958	021
0.958	023
0.958	024
0.958	025
0.960	AVERAGE

Small World Metrics...

NETWORK
Q1

Group A

Group Size 25
Potential Ties 600
Actual Ties 158
Density 26%

Computing geodesics
158 paths of length 1
411 paths of length 2
405 paths of length 3
193 paths of length 4
28 paths of length 5
0 paths of length 6

Name	CC	Avg. Path Length	Shortcuts
-----------	----	----------------	---------
012	0.23	1.00	0.04
005	0.35	1.38	0.00
020	0.37	1.92	0.13
001	0.41	1.58	0.00
015	0.50	2.92	1.00
017	0.50	2.50	0.25
019	0.50	3.08	0.00
004	0.52	1.88	0.00
002	0.54	1.96	0.00
007	0.54	2.00	0.00
016	0.55	2.33	0.25
018	0.55	3.08	0.00
009	0.57	1.88	0.33
025	0.57	2.71	0.00
014	0.61	2.04	0.00
011	0.63	1.63	0.00
008	0.65	2.25	0.00
003	0.66	1.75	0.00
006	0.69	2.00	0.00
021	0.70	2.71	0.00
023	0.70	2.71	0.00
024	0.70	2.71	0.00
013	0.77	1.75	0.00
010	0.77	1.88	0.00

022	0.83	0.00	0.00
-----------	----	---------------- ---------	
Overall	0.58	2.60	0.04

Small World Metrics...

NETWORK
Q1

Group A

Group Size 25
Potential Ties 600
Actual Ties 158
Density 26%

Computing geodesics
158 paths of length 1
411 paths of length 2
405 paths of length 3
193 paths of length 4
28 paths of length 5
0 paths of length 6

Name	CC	Avg. Path Length	Shortcuts
-----------	----	---------------- ---------	
022	0.83	0.00	0.00
012	0.23	1.00	0.04
005	0.35	1.38	0.00
001	0.41	1.58	0.00
011	0.63	1.63	0.00
003	0.66	1.75	0.00
013	0.77	1.75	0.00
004	0.52	1.88	0.00
009	0.57	1.88	0.33
010	0.77	1.88	0.00
020	0.37	1.92	0.13
002	0.54	1.96	0.00
006	0.69	2.00	0.00
007	0.54	2.00	0.00
014	0.61	2.04	0.00
008	0.65	2.25	0.00
016	0.55	2.33	0.25
017	0.50	2.50	0.25
021	0.70	2.71	0.00
023	0.70	2.71	0.00
024	0.70	2.71	0.00
025	0.57	2.71	0.00
015	0.50	2.92	1.00
018	0.55	3.08	0.00
019	0.50	3.08	0.00
-----------	----	---------------- ---------	
Overall	0.58	2.60	0.04

Individual Summary...

Network : Q1
- -

020	4
021	4
022	4
023	4
024	4

Group Populations...

National Corrosion & Wear	
National Corrosion & Wear	6
National Analytical Chem & Test	
National Analytical Chem & Tes	5
National Polymers/Composites	
National Polymers/Composites	6
National NDI	
National NDI	5
National Ind/Op Chemicals	
National Ind/Op Chemicals	6

National Metals/Ceramics	
National Metals/Ceramics	5
Site	
CHPT	3
China Lake	6
JAX	4
Lakehurst	4
North Island	2
PAX River	6
Level 3 Leadership Team	
Site Supervisors	6
Level 3	
Materials Competency	25

Network Centrality Q2

Network Centrality...

NETWORK
Q2

Group A

Group Size 25
Potential Ties 600
Actual Ties 132
Density 22%

Computing geodesics
132 paths of length 1
339 paths of length 2
310 paths of length 3
104 paths of length 4
45 paths of length 5
21 paths of length 6
0 paths of length 7

Group A : Degrees (Out)

1.000	012
0.417	001
0.417	004
0.417	005
0.333	023
0.292	006
0.292	011
0.250	013
0.250	019
0.208	007
0.208	021
0.208	022
0.208	025
0.167	002
0.167	010
0.167	016
0.125	009
0.125	017
0.125	018
0.042	015
0.042	020
0.042	024
0.000	003
0.000	008
0.000	014
0.220	AVERAGE
0.848	CENTRALIZATION

Group A : Degrees (In)

0.417	001
0.417	020
0.375	005
0.333	004
0.292	006
0.292	010
0.250	002
0.250	012
0.250	018
0.208	003
0.208	007
0.208	021
0.208	022
0.208	024
0.167	009
0.167	011
0.167	014
0.167	016
0.167	017
0.167	019
0.167	023
0.167	025
0.125	008
0.083	013
0.042	015
0.220	AVERAGE
0.214	CENTRALIZATION

Group A : Betweeness (White & Borgatti) : Uniform	
0.255	012
0.154	001
0.124	018
0.121	019
0.104	004
0.097	005
0.093	023
0.090	006
0.083	020
0.055	016
0.042	010
0.025	009
0.016	007
0.016	021
0.016	022
0.007	011
0.005	002
0.001	013
0.000	003
0.000	008
0.000	014
0.000	015
0.000	017
0.000	024
0.000	025
0.052	AVERAGE
0.211	CENTRALIZATION

Group A : Closeness (Out)	
1.000	012
0.632	005
0.585	006
0.585	011
0.571	001
0.571	013
0.545	010
0.533	004
0.533	009
0.522	023
0.480	019
0.462	007
0.453	002
0.436	016
0.393	021
0.393	022
0.393	025
0.353	017
0.353	018
0.270	020
0.222	024
0.043	015
0.042	003
0.042	008
0.042	014
0.418	AVERAGE
1.239	CENTRALIZATION

Group A : Closeness (In)	
0.240	014
0.202	003
0.188	020
0.186	001
0.183	004
0.183	018
0.182	006
0.182	008
0.180	005
0.174	015
0.173	010
0.173	021
0.173	022
0.171	002
0.170	012
0.170	016
0.170	017
0.170	019
0.169	007
0.169	009
0.168	011
0.168	024
0.162	023
0.162	025
0.155	013

0.177	AVERAGE
0.134	CENTRALIZATION

Group A : Power (Out)

0.627	012
0.364	005
0.363	001
0.338	006
0.319	004
0.307	023
0.301	019
0.296	011
0.294	010
0.286	013
0.279	009
0.245	016
0.239	007
0.239	018
0.229	002
0.205	021
0.205	022
0.197	025
0.176	017
0.176	020
0.111	024
0.022	015
0.021	003
0.021	008
0.021	014
0.235	AVERAGE

Group A : Power (In)

0.213	012
0.170	001
0.154	018
0.146	019
0.144	004
0.139	005
0.136	006
0.135	020
0.128	023
0.120	014
0.112	016
0.107	010
0.101	003
0.097	009
0.094	021
0.094	022
0.093	007
0.091	008
0.088	002
0.087	011
0.087	015
0.085	017
0.084	024
0.081	025
0.078	013
0.115	AVERAGE

Network Reach...

NETWORK
Q2

Group A
Group Size 25
Potential Ties 600
Actual Ties 132
Density 22%

Computing geodesics
132 paths of length 1
339 paths of length 2
310 paths of length 3
104 paths of length 4
45 paths of length 5
21 paths of length 6

Group A : Reach (Out) - 2 Steps

1.000	005
1.000	006
1.000	009
1.000	010
1.000	011

1.000	012
1.000	013
0.833	001
0.750	023
0.708	004
0.667	019
0.625	002
0.625	007
0.583	016
0.375	021
0.375	022
0.375	025
0.292	017
0.292	018
0.167	020
0.083	024
0.042	015
0.000	003
0.000	008
0.000	014
0.552	AVERAGE

Group A : Reach (In) - 2 Steps

0.792	018
0.750	001
0.750	004
0.750	006
0.750	020
0.625	005
0.625	021
0.625	022
0.583	003
0.542	002
0.542	009
0.542	010
0.542	014
0.500	007
0.500	011
0.500	012
0.500	024
0.458	016
0.458	017
0.458	019
0.458	023
0.458	025
0.417	008
0.375	013
0.292	015
0.552	AVERAGE

Group A : Reach (Out) - 3 Steps

1.000	001
1.000	002
1.000	004
1.000	005
1.000	006
1.000	007
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	019
1.000	023
0.958	016
0.875	021
0.875	022
0.875	025
0.750	017
0.750	018
0.333	020
0.208	024
0.042	015
0.000	003
0.000	008
0.000	014
0.747	AVERAGE

Group A : Reach (In) - 3 Steps

0.833	014
0.833	016
0.833	017
0.833	018
0.833	019
0.833	020
0.792	001
0.792	003

0.792	004
0.792	005
0.792	006
0.750	002
0.750	007
0.750	009
0.750	010
0.750	011
0.750	012
0.750	021
0.750	022
0.708	024
0.667	023
0.667	025
0.583	008
0.542	013
0.542	015
0.747	AVERAGE

Group A : Reach (Out) - 4 Steps

1.000	001
1.000	002
1.000	004
1.000	005
1.000	006
1.000	007
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	016
1.000	017
1.000	018
1.000	019
1.000	021
1.000	022
1.000	023
1.000	025
0.750	020
0.375	024
0.042	015
0.000	003
0.000	008
0.000	014
0.807	AVERAGE

Group A : Reach (In) - 4 Steps

0.875	014
0.833	001
0.833	003
0.833	004
0.833	005
0.833	006
0.833	016
0.833	017
0.833	018
0.833	019
0.833	020
0.792	002
0.792	007
0.792	008
0.792	009
0.792	010
0.792	011
0.792	012
0.792	015
0.792	021
0.792	022
0.792	024
0.750	013
0.750	023
0.750	025
0.807	AVERAGE

Group A : Reach (Out) - 5 Steps

1.000	001
1.000	002
1.000	004
1.000	005
1.000	006
1.000	007
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013

1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	021
1.000	022
1.000	023
1.000	025
0.792	024
0.042	015
0.000	003
0.000	008
0.000	014
0.833	AVERAGE

Group A : Reach (In) - 5 Steps

0.917	014
0.875	003
0.833	001
0.833	002
0.833	004
0.833	005
0.833	006
0.833	007
0.833	008
0.833	009
0.833	010
0.833	011
0.833	012
0.833	015
0.833	016
0.833	017
0.833	018
0.833	019
0.833	020
0.833	021
0.833	022
0.833	024
0.792	013
0.792	023
0.792	025
0.833	AVERAGE

Group A : Reach (Out) - 6 Steps

1.000	001
1.000	002
1.000	004
1.000	005
1.000	006
1.000	007
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	021
1.000	022
1.000	023
1.000	024
1.000	025
0.042	015
0.000	003
0.000	008
0.000	014
0.842	AVERAGE

Group A : Reach (In) - 6 Steps

0.917	014
0.875	003
0.875	008
0.875	015
0.833	001
0.833	002
0.833	004
0.833	005
0.833	006
0.833	007
0.833	009
0.833	010
0.833	011
0.833	012

0.833	013
0.833	016
0.833	017
0.833	018
0.833	019
0.833	020
0.833	021
0.833	022
0.833	023
0.833	024
0.833	025
0.841	AVERAGE

Small World Metrics...

NETWORK
Q2

Group A
Group Size 25
Potential Ties 600
Actual Ties 132
Density 22%

Computing geodesics
132 paths of length 1
339 paths of length 2
310 paths of length 3
104 paths of length 4
45 paths of length 5
21 paths of length 6
0 paths of length 7

Name	CC	Avg. Path Length	Shortcuts
001	0.29	1.75	0.00
002	0.61	2.21	0.00
003	0.90	0.00	0.00
004	0.33	1.88	0.00
005	0.32	1.58	0.00
006	0.38	1.71	0.00
007	0.50	2.17	0.00
008	0.83	0.00	0.00
009	0.45	1.88	0.33
010	0.62	1.83	0.00
011	0.63	1.71	0.00
012	0.18	1.00	0.04
013	0.70	1.75	0.00
014	0.50	0.00	0.00
015	0.50	0.04	1.00
016	0.50	2.29	0.25
017	0.75	2.83	0.00
018	0.47	2.83	0.00
019	0.50	2.08	0.00
020	0.42	3.71	1.00
021	0.52	2.54	0.00
022	0.52	2.54	0.00
023	0.46	1.92	0.00
024	0.70	4.50	1.00
025	0.60	2.54	0.00
Overall	0.53	2.64	0.05

Q3
Network Centrality...

NETWORK
Q3

Group A

Group Size 25
Potential Ties 600
Actual Ties 180
Density 30%

Computing geodesics
180 paths of length 1

574 paths of length 2
413 paths of length 3
86 paths of length 4
0 paths of length 5

Group A : Degrees (Out)

1.000	012
0.583	001
0.583	005
0.500	014
0.417	010
0.375	004
0.375	007
0.333	002
0.333	011
0.250	013
0.250	022
0.208	006
0.208	015
0.208	018
0.208	019
0.208	020
0.208	021
0.208	023
0.208	024
0.208	025
0.167	008
0.167	009
0.167	016
0.125	017
0.000	003
0.300	AVERAGE
0.761	CENTRALIZATION

Group A : Degrees (In)

0.542	005
0.500	010
0.458	001
0.458	012
0.417	004
0.417	007
0.375	006
0.375	014
0.375	020
0.333	009
0.333	011
0.292	008
0.250	013
0.250	018
0.250	019
0.250	021
0.208	003
0.208	022
0.208	023
0.208	024
0.208	025
0.167	002
0.167	016
0.167	017
0.083	015
0.300	AVERAGE
0.263	CENTRALIZATION

Group A : Betweeness (White & Borgatti) : Uniform

0.288	012
0.142	005
0.127	020
0.095	014
0.076	001
0.043	018
0.038	010
0.033	004
0.028	019
0.025	006
0.024	022
0.017	007
0.012	011
0.012	016
0.009	021
0.006	008
0.004	009
0.003	013
0.003	015
0.002	002
0.000	003
0.000	017

0.000	023
0.000	024
0.000	025
0.039	AVERAGE
0.259	CENTRALIZATION

Group A : Closeness (Out)

1.000	012
0.706	001
0.706	005
0.667	014
0.632	010
0.615	004
0.600	002
0.600	011
0.571	013
0.558	006
0.545	008
0.545	009
0.522	007
0.511	022
0.500	015
0.490	019
0.490	020
0.471	016
0.471	018
0.414	021
0.414	023
0.414	024
0.414	025
0.364	017
0.042	003
0.530	AVERAGE
0.999	CENTRALIZATION

Group A : Closeness (In)

0.500	003
0.421	005
0.393	004
0.393	006
0.393	014
0.387	010
0.387	020
0.381	001
0.375	012
0.369	007
0.369	018
0.358	009
0.358	011
0.348	008
0.348	019
0.338	013
0.338	021
0.333	022
0.333	023
0.333	024
0.333	025
0.329	016
0.329	017
0.316	015
0.300	002
0.362	AVERAGE
0.293	CENTRALIZATION

Group A : Power (Out)

0.644	012
0.424	005
0.391	001
0.381	014
0.335	010
0.324	004
0.308	020
0.306	011
0.301	002
0.292	006
0.287	013
0.276	008
0.275	009
0.269	007
0.267	022
0.259	019
0.257	018
0.251	015
0.241	016

0.211	021
0.207	023
0.207	024
0.207	025
0.182	017
0.021	003
0.285	AVERAGE

Group A : Power (In)

0.332	012
0.281	005
0.257	020
0.250	003
0.244	014
0.228	001
0.213	004
0.212	010
0.209	006
0.206	018
0.193	007
0.188	019
0.185	011
0.181	009
0.179	022
0.177	008
0.173	021
0.170	013
0.170	016
0.167	023
0.167	024
0.167	025
0.164	017
0.159	015
0.151	002
0.201	AVERAGE

Network Reach...

NETWORK
Q3

Group A

Group Size 25
Potential Ties 600
Actual Ties 180
Density 30%

Computing geodesics
180 paths of length 1
574 paths of length 2
413 paths of length 3
86 paths of length 4
0 paths of length 5

Group A : Reach (Out) - 2 Steps

1.000	001
1.000	002
1.000	004
1.000	005
1.000	006
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
0.792	015
0.792	022
0.750	019
0.750	020
0.708	007
0.708	016
0.667	018
0.417	021
0.417	023
0.417	024
0.417	025
0.333	017
0.000	003
0.767	AVERAGE

Group A : Reach (In) - 2 Steps

0.958	005
0.958	006
0.958	014
0.917	004
0.917	018
0.917	020
0.792	001
0.792	003
0.792	010
0.750	007
0.750	009
0.750	011
0.750	012
0.750	019
0.708	008
0.708	021
0.708	022
0.708	023
0.708	024
0.708	025
0.667	013
0.667	016
0.667	017
0.625	015
0.542	002
0.767	AVERAGE

Group A : Reach (Out) - 3 Steps

1.000	001
1.000	002
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	018
1.000	019
1.000	020
1.000	022
0.958	021
0.958	023
0.958	024
0.958	025
0.792	017
0.000	003
0.945	AVERAGE

Group A : Reach (In) - 3 Steps

1.000	003
0.958	001
0.958	004
0.958	005
0.958	006
0.958	007
0.958	008
0.958	009
0.958	010
0.958	011
0.958	012
0.958	013
0.958	014
0.958	015
0.958	016
0.958	017
0.958	018
0.958	019
0.958	020
0.917	021
0.917	022
0.917	023
0.917	024
0.917	025
0.792	002
0.945	AVERAGE

Group A : Reach (Out) - 4 Steps

1.000	001
1.000	002

1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	021
1.000	022
1.000	023
1.000	024
1.000	025
0.000	003
0.960	AVERAGE

Group A : Reach (In) - 4 Steps

1.000	003
0.958	001
0.958	002
0.958	004
0.958	005
0.958	006
0.958	007
0.958	008
0.958	009
0.958	010
0.958	011
0.958	012
0.958	013
0.958	014
0.958	015
0.958	016
0.958	017
0.958	018
0.958	019
0.958	020
0.958	021
0.958	022
0.958	023
0.958	024
0.958	025
0.960	AVERAGE

Group A : Reach (Out) - 5 Steps

1.000	001
1.000	002
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	021
1.000	022
1.000	023
1.000	024
1.000	025
0.000	003
0.960	AVERAGE

Group A : Reach (In) - 5 Steps

1.000	003
0.958	001
0.958	002
0.958	004
0.958	005

0.958	006
0.958	007
0.958	008
0.958	009
0.958	010
0.958	011
0.958	012
0.958	013
0.958	014
0.958	015
0.958	016
0.958	017
0.958	018
0.958	019
0.958	020
0.958	021
0.958	022
0.958	023
0.958	024
0.958	025
0.960	AVERAGE

Group A : Reach (Out) - 6 Steps

1.000	001
1.000	002
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	021
1.000	022
1.000	023
1.000	024
1.000	025
0.000	003
0.960	AVERAGE

Group A : Reach (In) - 6 Steps

1.000	003
0.958	001
0.958	002
0.958	004
0.958	005
0.958	006
0.958	007
0.958	008
0.958	009
0.958	010
0.958	011
0.958	012
0.958	013
0.958	014
0.958	015
0.958	016
0.958	017
0.958	018
0.958	019
0.958	020
0.958	021
0.958	022
0.958	023
0.958	024
0.958	025
0.960	AVERAGE

Small World Metrics...

NETWORK
Q3

Group A
Group Size 25

Potential Ties 600
Actual Ties 180
Density 30%

Computing geodesics
180 paths of length 1
574 paths of length 2
413 paths of length 3
86 paths of length 4
0 paths of length 5

Name	CC	Avg. Path Length	Shortcuts
-----------	----	----------------	---------
001	0.43	1.42	0.00
002	0.72	1.67	0.00
003	1.00	0.00	0.00
004	0.54	1.63	0.00
005	0.39	1.42	0.00
006	0.58	1.79	0.00
007	0.63	1.92	0.00
008	0.57	1.83	0.00
009	0.79	1.83	0.00
010	0.56	1.58	0.00
011	0.79	1.67	0.00
012	0.26	1.00	0.00
013	0.86	1.75	0.00
014	0.47	1.50	0.00
015	0.53	2.00	0.20
016	0.60	2.13	0.25
017	0.75	2.75	0.00
018	0.48	2.13	0.00
019	0.57	2.04	0.00
020	0.44	2.04	0.00
021	0.52	2.42	0.00
022	0.60	1.96	0.00
023	0.70	2.42	0.00
024	0.70	2.42	0.00
025	0.70	2.42	0.00
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Overall	0.61	2.32	0.01

Network Centrality...

NETWORK
Q4

Group A
Group Size 25
Potential Ties 600
Actual Ties 138
Density 23%

Computing geodesics
138 paths of length 1
355 paths of length 2
224 paths of length 3
51 paths of length 4
0 paths of length 5

Group A : Degrees (Out)

1.000	012
0.542	001
0.458	014
0.417	005
0.375	007
0.333	004
0.250	009
0.250	013
0.208	003
0.208	011
0.208	022
0.208	023
0.208	025
0.167	002
0.167	006
0.167	010
0.167	016
0.125	017
0.125	018
0.125	019
0.042	015
0.000	008
0.000	020
0.000	021
0.000	024
0.230	AVERAGE
0.837	CENTRALIZATION

Group A : Degrees (In)

0.542	001
0.375	005
0.375	010
0.333	006
0.333	020
0.292	003
0.292	004
0.292	018
0.250	007
0.250	012
0.250	014
0.208	011
0.208	016
0.208	017
0.167	009
0.167	019
0.167	021
0.167	023
0.167	024
0.125	002
0.125	008
0.125	013
0.125	022
0.125	025
0.083	015
0.230	AVERAGE
0.339	CENTRALIZATION

Group A : Betweeness (White & Borgatti) : Uniform

0.316	001

0.188	012
0.139	016
0.086	014
0.067	005
0.060	023
0.037	010
0.025	004
0.022	009
0.018	007
0.012	018
0.009	011
0.003	003
0.003	006
0.003	013
0.002	017
0.001	002
0.000	008
0.000	015
0.000	019
0.000	020
0.000	021
0.000	022
0.000	024
0.000	025
0.040	AVERAGE
0.288	CENTRALIZATION

Group A : Closeness (Out)

1.000	012
0.686	001
0.649	014
0.632	005
0.571	009
0.571	013
0.558	011
0.545	007
0.545	010
0.533	004
0.471	003
0.462	006
0.453	002
0.444	016
0.400	015
0.320	017
0.320	018
0.320	019
0.052	022
0.052	023
0.052	025
0.042	008
0.042	020
0.042	021
0.042	024
0.392	AVERAGE
1.294	CENTRALIZATION

Group A : Closeness (In)

0.220	020
0.195	021
0.195	024
0.176	023
0.164	022
0.164	025
0.128	008
0.127	001
0.123	018
0.122	005
0.122	010
0.121	003
0.121	004
0.121	006
0.121	014
0.121	016
0.121	017
0.119	009
0.118	002
0.118	007
0.118	012
0.118	019
0.117	011
0.114	013
0.114	015
0.136	AVERAGE
0.179	CENTRALIZATION

Group A : Power (Out)

0.594	012
0.501	001
0.367	014
0.349	005
0.297	009
0.292	016
0.291	010
0.287	013
0.284	011
0.282	007
0.279	004
0.237	003
0.232	006
0.227	002
0.200	015
0.166	018
0.161	017
0.160	019
0.056	023
0.026	022
0.026	025
0.021	008
0.021	020
0.021	021
0.021	024
0.216	AVERAGE

Group A : Power (In)

0.221	001
0.153	012
0.130	016
0.118	023
0.110	020
0.103	014
0.098	021
0.098	024
0.095	005
0.082	022
0.082	025
0.080	010
0.073	004
0.071	009
0.068	007
0.068	018
0.064	008
0.063	011
0.062	003
0.062	006
0.062	017
0.060	002
0.059	013
0.059	019
0.057	015
0.088	AVERAGE

Network Reach...

NETWORK
Q4

Group A

Group Size 25
Potential Ties 600
Actual Ties 138
Density 23%

Computing geodesics
138 paths of length 1
355 paths of length 2
224 paths of length 3
51 paths of length 4
0 paths of length 5

Group A : Reach (Out) - 2 Steps

1.000	001
1.000	005
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
0.792	004
0.792	007

0.667	003
0.667	006
0.625	002
0.583	016
0.458	015
0.208	022
0.208	023
0.208	025
0.167	017
0.167	018
0.167	019
0.000	008
0.000	020
0.000	021
0.000	024
0.548	AVERAGE

Group A : Reach (In) - 2 Steps

0.750	020
0.708	001
0.708	018
0.667	016
0.667	017
0.667	023
0.583	003
0.583	004
0.583	005
0.583	009
0.583	010
0.583	014
0.542	002
0.542	006
0.542	007
0.542	012
0.458	011
0.458	019
0.458	021
0.458	024
0.417	008
0.417	015
0.417	022
0.417	025
0.375	013
0.548	AVERAGE

Group A : Reach (Out) - 3 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
0.583	017
0.583	018
0.583	019
0.208	022
0.208	023
0.208	025
0.000	008
0.000	020
0.000	021
0.000	024
0.695	AVERAGE

Group A : Reach (In) - 3 Steps

0.875	020
0.833	023
0.750	021
0.750	024
0.708	001
0.708	002
0.708	003
0.708	004
0.708	005
0.708	006
0.708	009
0.708	010
0.708	014

0.708	016
0.708	017
0.708	018
0.708	019
0.708	022
0.708	025
0.625	008
0.583	007
0.583	011
0.583	012
0.583	013
0.583	015
0.695	AVERAGE

Group A : Reach (Out) - 4 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
0.208	022
0.208	023
0.208	025
0.000	008
0.000	020
0.000	021
0.000	024
0.745	AVERAGE

Group A : Reach (In) - 4 Steps

0.875	020
0.875	021
0.875	024
0.833	022
0.833	023
0.833	025
0.750	008
0.708	001
0.708	002
0.708	003
0.708	004
0.708	005
0.708	006
0.708	007
0.708	009
0.708	010
0.708	011
0.708	012
0.708	013
0.708	014
0.708	015
0.708	016
0.708	017
0.708	018
0.708	019
0.745	AVERAGE

Group A : Reach (Out) - 5 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017

1.000	018
1.000	019
0.208	022
0.208	023
0.208	025
0.000	008
0.000	020
0.000	021
0.000	024
0.745	AVERAGE

Group A : Reach (In) - 5 Steps

0.875	020
0.875	021
0.875	024
0.833	022
0.833	023
0.833	025
0.750	008
0.708	001
0.708	002
0.708	003
0.708	004
0.708	005
0.708	006
0.708	007
0.708	009
0.708	010
0.708	011
0.708	012
0.708	013
0.708	014
0.708	015
0.708	016
0.708	017
0.708	018
0.708	019
0.745	AVERAGE

Group A : Reach (Out) - 6 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
0.208	022
0.208	023
0.208	025
0.000	008
0.000	020
0.000	021
0.000	024
0.745	AVERAGE

Group A : Reach (In) - 6 Steps

0.875	020
0.875	021
0.875	024
0.833	022
0.833	023
0.833	025
0.750	008
0.708	001
0.708	002
0.708	003
0.708	004
0.708	005
0.708	006
0.708	007
0.708	009
0.708	010
0.708	011
0.708	012
0.708	013

0.708	014
0.708	015
0.708	016
0.708	017
0.708	018
0.708	019
0.745	AVERAGE

Small World Metrics...

NETWORK
Q4

Group A
Group Size 25
Potential Ties 600
Actual Ties 138
Density 23%

Computing geodesics
138 paths of length 1
355 paths of length 2
224 paths of length 3
51 paths of length 4
0 paths of length 5

Name	CC	Avg. Path Length	Shortcuts
001	0.30	1.46	0.15
002	0.70	2.21	0.00
003	0.61	2.13	0.00
004	0.63	1.88	0.00
005	0.42	1.58	0.00
006	0.61	2.17	0.00
007	0.52	1.83	0.00
008	0.83	0.00	0.00
009	0.50	1.75	0.00
010	0.63	1.83	0.00
011	0.63	1.79	0.00
012	0.20	1.00	0.00
013	0.63	1.75	0.00
014	0.41	1.54	0.00
015	1.00	2.50	1.00
016	0.60	2.25	0.25
017	0.65	3.13	0.00
018	0.55	3.13	0.00
019	0.75	3.13	0.00
020	0.48	0.00	0.00
021	0.75	0.00	0.00
022	0.43	0.21	0.00
023	0.36	0.21	0.00
024	0.75	0.00	0.00
025	0.43	0.21	0.00
Overall	0.57	2.24	0.03

Q4
Q5
Network Centrality...

NETWORK
Q5

Group A
Group Size 25
Potential Ties 600
Actual Ties 164
Density 27%

Computing geodesics
164 paths of length 1
537 paths of length 2
440 paths of length 3
121 paths of length 4
0 paths of length 5

Group A : Degrees (Out)

1.000	012
0.708	001
0.458	014
0.458	018
0.417	007
0.375	005
0.333	004
0.333	006
0.333	019
0.292	009
0.250	010
0.250	011
0.250	013
0.250	023
0.208	021
0.208	022
0.167	016
0.125	017
0.083	002
0.083	008
0.083	020
0.042	003
0.042	015
0.042	024
0.042	025
0.273	AVERAGE
0.790	CENTRALIZATION

Group A : Degrees (In)

0.667	001
0.500	020
0.458	004
0.458	007
0.458	010
0.458	014
0.375	005
0.375	006
0.333	012
0.292	018
0.208	009
0.208	011
0.208	016
0.208	017
0.208	019
0.208	025
0.167	013
0.167	023
0.167	024
0.125	002
0.125	003
0.125	008
0.125	021
0.125	022
0.083	015
0.273	AVERAGE
0.428	CENTRALIZATION

Group A : Betweeness (White & Borgatti) : Uniform

0.335	001
0.199	012
0.144	020
0.131	014
0.068	007
0.067	004
0.038	018
0.035	023
0.029	009
0.018	010
0.015	005
0.012	006
0.012	019
0.007	013
0.004	011
0.004	016
0.000	002
0.000	003
0.000	008
0.000	015
0.000	017
0.000	021
0.000	022
0.000	024
0.000	025
0.045	AVERAGE
0.302	CENTRALIZATION

Group A : Closeness (Out)	
1.000	012
0.774	001
0.649	014
0.615	005
0.600	004
0.600	018
0.585	007
0.585	009
0.571	010
0.571	011
0.571	013
0.558	006
0.522	019
0.471	002
0.471	016
0.462	020
0.462	023
0.444	003
0.407	008
0.400	015
0.393	017
0.393	021
0.393	022
0.329	024
0.324	025
0.526	AVERAGE
1.009	CENTRALIZATION

Group A : Closeness (In)	
0.750	001
0.649	014
0.649	020
0.615	004
0.585	007
0.585	010
0.558	005
0.558	006
0.533	012
0.511	018
0.511	025
0.490	009
0.490	023
0.480	016
0.480	017
0.480	019
0.462	013
0.453	003
0.444	011
0.421	015
0.414	024
0.400	002
0.393	008
0.393	021
0.393	022
0.508	AVERAGE
0.515	CENTRALIZATION

Group A : Power (Out)	
0.599	012
0.554	001
0.390	014
0.333	004
0.327	007
0.319	018
0.315	005
0.307	009
0.303	020
0.295	010
0.289	013
0.288	011
0.285	006
0.267	019
0.248	023
0.237	016
0.235	002
0.222	003
0.203	008
0.200	015
0.197	017
0.197	021
0.197	022
0.164	024
0.162	025

0.285	AVERAGE

Group A : Power (In)

0.542	001
0.396	020
0.390	014
0.366	012
0.341	004
0.327	007
0.302	010
0.287	005
0.285	006
0.275	018
0.263	023
0.259	009
0.255	025
0.246	019
0.242	016
0.240	017
0.234	013
0.226	003
0.224	011
0.211	015
0.207	024
0.200	002
0.197	008
0.197	021
0.197	022
0.276	AVERAGE

Network Reach...

NETWORK
Q5

Group A

Group Size 25
Potential Ties 600
Actual Ties 164
Density 27%

Computing geodesics
164 paths of length 1
537 paths of length 2
440 paths of length 3
121 paths of length 4
0 paths of length 5

Group A : Reach (Out) - 2 Steps

1.000	001
1.000	004
1.000	005
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
0.875	006
0.875	007
0.875	018
0.792	002
0.750	019
0.750	020
0.708	003
0.708	016
0.583	023
0.458	008
0.458	015
0.458	017
0.333	021
0.333	022
0.125	024
0.125	025
0.728	AVERAGE

Group A : Reach (In) - 2 Steps

1.000	001
1.000	014
0.958	020
0.917	004
0.833	005
0.833	006
0.833	007

0.833	010
0.833	025
0.792	012
0.792	023
0.750	009
0.750	018
0.708	016
0.708	017
0.708	019
0.667	003
0.667	013
0.625	011
0.542	002
0.542	015
0.500	008
0.500	024
0.458	021
0.458	022
0.728	AVERAGE

Group A : Reach (Out) - 3 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	018
1.000	019
1.000	020
1.000	023
0.917	021
0.917	022
0.875	017
0.792	024
0.750	025
0.970	AVERAGE

Group A : Reach (In) - 3 Steps

1.000	001
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	009
1.000	010
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	023
1.000	025
0.917	011
0.917	024
0.875	021
0.875	022
0.833	002
0.833	008
0.970	AVERAGE

Group A : Reach (Out) - 4 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010

1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	021
1.000	022
1.000	023
1.000	024
1.000	025
1.000	AVERAGE

Group A : Reach (In) - 4 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	021
1.000	022
1.000	023
1.000	024
1.000	025
1.000	AVERAGE

Group A : Reach (Out) - 5 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	021
1.000	022
1.000	023
1.000	024
1.000	025
1.000	AVERAGE

Group A : Reach (In) - 5 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016

1.000	017
1.000	018
1.000	019
1.000	020
1.000	021
1.000	022
1.000	023
1.000	024
1.000	025
1.000	AVERAGE

Group A : Reach (Out) - 6 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	021
1.000	022
1.000	023
1.000	024
1.000	025
1.000	AVERAGE

Group A : Reach (In) - 6 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	020
1.000	021
1.000	022
1.000	023
1.000	024
1.000	025
1.000	AVERAGE

Small World Metrics...

NETWORK
Q5

Group A
Group Size 25
Potential Ties 600
Actual Ties 164
Density 27%

Computing geodesics
164 paths of length 1
537 paths of length 2
440 paths of length 3
121 paths of length 4

0 paths of length 5

Name	CC	Avg. Path Length	Shortcuts
-----------	----	---------------- ---------	
001	0.31	1.29	0.00
002	0.75	2.13	0.00
003	0.83	2.25	1.00
004	0.51	1.67	0.00
005	0.62	1.63	0.00
006	0.58	1.79	0.00
007	0.52	1.71	0.10
008	0.83	2.46	0.00
009	0.71	1.71	0.00
010	0.66	1.75	0.00
011	0.80	1.75	0.00
012	0.24	1.00	0.00
013	0.60	1.75	0.00
014	0.55	1.54	0.00
015	1.00	2.50	1.00
016	0.80	2.13	0.00
017	0.85	2.54	0.00
018	0.58	1.67	0.00
019	0.60	1.92	0.00
020	0.40	2.17	0.00
021	0.50	2.54	0.00
022	0.50	2.54	0.00
023	0.43	2.17	0.17
024	0.65	3.04	1.00
025	0.60	3.08	1.00
-----------	----	---------------- ---------	
Overall	0.62	2.41	0.04

Individual Summary...
Network : Q5
- -

020 Brandy Corley 4

Q6
Network Centrality...

NETWORK
Q6

Group A

Group Size 25
Potential Ties 600
Actual Ties 142
Density 24%

Computing geodesics
142 paths of length 1
405 paths of length 2
321 paths of length 3
116 paths of length 4
0 paths of length 5

Group A : Degrees (Out)

1.000	012
0.625	001
0.417	005
0.417	007
0.417	014
0.333	004
0.333	009
0.250	006
0.250	010
0.250	013
0.208	011
0.208	022
0.208	023
0.167	002
0.167	016
0.125	017
0.125	018
0.125	019
0.083	008
0.083	025
0.042	003
0.042	015
0.042	024
0.000	020
0.000	021
0.237	AVERAGE

0.830	CENTRALIZATION

Group A : Degrees (In)

0.542	001
0.417	010
0.375	004
0.375	007
0.333	005
0.333	006
0.333	014
0.333	020
0.292	012
0.292	018
0.250	011
0.208	009
0.208	016
0.208	017
0.167	003
0.167	013
0.167	019
0.167	025
0.125	002
0.125	008
0.125	021
0.125	024
0.083	015
0.083	022
0.083	023
0.237	AVERAGE
0.332	CENTRALIZATION

Group A : Betweeness (White & Borgatti) : Uniform

0.328	001
0.294	012
0.126	016
0.121	011
0.077	025
0.075	014
0.051	007
0.037	009
0.031	005
0.025	004
0.023	010
0.013	013
0.010	018
0.005	006
0.002	017
0.001	002
0.000	003
0.000	008
0.000	015
0.000	019
0.000	020
0.000	021
0.000	022
0.000	023
0.000	024
0.049	AVERAGE
0.291	CENTRALIZATION

Group A : Closeness (Out)

1.000	012
0.727	001
0.632	005
0.632	014
0.600	009
0.571	010
0.571	013
0.558	007
0.558	011
0.533	004
0.500	006
0.471	002
0.462	016
0.429	003
0.407	008
0.393	015
0.381	025
0.329	017
0.329	018
0.329	019
0.324	022
0.324	023
0.043	024
0.042	020
0.042	021

0.447	AVERAGE
1.176	CENTRALIZATION

Group A : Closeness (In)

0.364	020
0.233	001
0.231	021
0.231	024
0.220	010
0.218	004
0.214	012
0.212	007
0.212	018
0.211	005
0.211	006
0.211	014
0.209	025
0.207	016
0.207	017
0.205	011
0.205	013
0.203	009
0.200	003
0.197	019
0.192	002
0.190	008
0.189	022
0.189	023
0.188	015
0.214	AVERAGE
0.319	CENTRALIZATION

Group A : Power (Out)

0.647	012
0.528	001
0.353	014
0.340	011
0.331	005
0.318	009
0.305	007
0.297	010
0.294	016
0.292	013
0.279	004
0.252	006
0.236	002
0.229	025
0.214	003
0.203	008
0.197	015
0.169	018
0.165	017
0.164	019
0.162	022
0.162	023
0.022	024
0.021	020
0.021	021
0.248	AVERAGE

Group A : Power (In)

0.281	001
0.254	012
0.182	020
0.167	016
0.163	011
0.143	014
0.143	025
0.132	007
0.122	004
0.121	005
0.121	010
0.120	009
0.115	021
0.115	024
0.111	018
0.109	013
0.108	006
0.104	017
0.100	003
0.098	019
0.096	002
0.095	008
0.094	015
0.094	022

0.094	023
0.131	AVERAGE

Network Reach...

NETWORK
Q6

Group A
Group Size 25
Potential Ties 600
Actual Ties 142
Density 24%

Computing geodesics
142 paths of length 1
405 paths of length 2
321 paths of length 3
116 paths of length 4
0 paths of length 5

Group A : Reach (Out) - 2 Steps

1.000	001
1.000	005
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
0.792	004
0.792	007
0.750	006
0.708	002
0.667	016
0.625	003
0.458	008
0.417	015
0.292	025
0.250	022
0.250	023
0.167	017
0.167	018
0.167	019
0.042	024
0.000	020
0.000	021
0.582	AVERAGE

Group A : Reach (In) - 2 Steps

0.792	001
0.792	020
0.708	018
0.667	004
0.667	010
0.667	012
0.667	016
0.667	017
0.667	025
0.625	005
0.625	006
0.625	007
0.625	011
0.625	014
0.583	009
0.583	013
0.542	003
0.500	002
0.458	008
0.458	019
0.417	015
0.417	021
0.417	024
0.375	022
0.375	023
0.582	AVERAGE

Group A : Reach (Out) - 3 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005

1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	025
0.667	017
0.667	018
0.667	019
0.458	022
0.458	023
0.042	024
0.000	020
0.000	021
0.798	AVERAGE

Group A : Reach (In) - 3 Steps

0.958	020
0.875	001
0.875	004
0.875	010
0.875	012
0.875	013
0.875	025
0.792	003
0.792	005
0.792	006
0.792	007
0.792	009
0.792	014
0.792	016
0.792	017
0.792	018
0.792	019
0.792	021
0.792	024
0.750	011
0.750	022
0.750	023
0.667	002
0.667	008
0.667	015
0.799	AVERAGE

Group A : Reach (Out) - 4 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	022
1.000	023
1.000	025
0.042	024
0.000	020
0.000	021
0.882	AVERAGE

Group A : Reach (In) - 4 Steps

0.958	020
0.917	021
0.917	024
0.875	001
0.875	002
0.875	003
0.875	004
0.875	005

0.875	006
0.875	007
0.875	008
0.875	009
0.875	010
0.875	011
0.875	012
0.875	013
0.875	014
0.875	015
0.875	016
0.875	017
0.875	018
0.875	019
0.875	022
0.875	023
0.875	025
0.882	AVERAGE

Group A : Reach (Out) - 5 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011
1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	022
1.000	023
1.000	025
0.042	024
0.000	020
0.000	021
0.882	AVERAGE

Group A : Reach (In) - 5 Steps

0.958	020
0.917	021
0.917	024
0.875	001
0.875	002
0.875	003
0.875	004
0.875	005
0.875	006
0.875	007
0.875	008
0.875	009
0.875	010
0.875	011
0.875	012
0.875	013
0.875	014
0.875	015
0.875	016
0.875	017
0.875	018
0.875	019
0.875	022
0.875	023
0.875	025
0.882	AVERAGE

Group A : Reach (Out) - 6 Steps

1.000	001
1.000	002
1.000	003
1.000	004
1.000	005
1.000	006
1.000	007
1.000	008
1.000	009
1.000	010
1.000	011

1.000	012
1.000	013
1.000	014
1.000	015
1.000	016
1.000	017
1.000	018
1.000	019
1.000	022
1.000	023
1.000	025
0.042	024
0.000	020
0.000	021
0.882	AVERAGE

Group A : Reach (In) - 6 Steps

0.958	020
0.917	021
0.917	024
0.875	001
0.875	002
0.875	003
0.875	004
0.875	005
0.875	006
0.875	007
0.875	008
0.875	009
0.875	010
0.875	011
0.875	012
0.875	013
0.875	014
0.875	015
0.875	016
0.875	017
0.875	018
0.875	019
0.875	022
0.875	023
0.875	025
0.882	AVERAGE

Small World Metrics...

NETWORK
Q6

Group A

Group Size 25
Potential Ties 600
Actual Ties 142
Density 24%

Computing geodesics
142 paths of length 1
405 paths of length 2
321 paths of length 3
116 paths of length 4
0 paths of length 5

Name	CC	Avg. Path Length	Shortcuts
-----------	----	----------------	---------
001	0.31	1.38	0.00
002	0.76	2.13	0.00
003	0.92	2.33	1.00
004	0.56	1.88	0.00
005	0.44	1.58	0.00
006	0.72	2.00	0.00
007	0.55	1.79	0.10
008	0.83	2.46	0.00
009	0.70	1.67	0.00
010	0.68	1.75	0.00
011	0.60	1.79	0.00
012	0.20	1.00	0.00
013	0.63	1.75	0.00
014	0.48	1.58	0.00
015	1.00	2.54	1.00

016	0.65		2.17	0.25
017	0.70		3.04	0.00
018	0.57		3.04	0.00
019	0.75		3.04	0.00
020	0.41		0.00	0.00
021	0.67		0.00	0.00
022	0.37		3.08	0.20
023	0.37		3.08	0.20
024	0.58		0.04	1.00
025	0.43		2.63	1.00
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Overall	0.60		2.42	0.06

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